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# Red Bull RB20

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## COVER STORY

**6 Formula 1**
Why Red Bull has seen its authority challenged

## COLUMN

**5 Andrew Cotton**
When should a champion driver call it a day?

## FEATURES

**12 Formula 1**
Williams' struggles and solutions with the FW46...

**18 WGTP**
... and why it has set up a new applied engineering company

**22 Le Mans**
Season review of the LMH cars

**26 Future of motorsport**
What might we expect to see in the next 20 years?

**32 Super GT**
The road ahead for the premier Japanese sportscar championship

**41 Formula Vee**
Single seaters with Beetle engines and quirky suspension

## TECHNICAL

**46 Miller engines**
The rise of the Miller / Offenhauser engine dynasty

**56 AP Racing brakes**
The story of the move to spec brakes for NASCAR

**64 Electronics**
Marelli's pioneering AI-integrated control unit

**70 Danny Nowlan**
Hammerimg home the importance of a lost art

## BUSINESS

**76 News**
WEC entry movements, Euro NASCAR goes sequential and the end of hybrids in two series

**81 Chris Aylett**
On the challenges facing our industry in 2025

**82 Bump stop**

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# Arctic circles

## Is it better to carry on trying to win, or to go out on a high?

It was in January 2003 that Mika Häkkinen, the two-time Formula 1 world champion, took part in his first rally, behind the wheel of a Mitsubishi Lancer on the Arctic Lapland Rally.

In temperatures at times below -30degC, Häkkinen made two trips to the rally site at Rovaniemi in Finland, one in mid-January to experience the car on ice for the first time, the second for the contest itself. I went out on stage during the first test, and stood in a forest with photographer, Bryn Williams, waiting for Häkkinen to come through. When he did, he missed his braking point, heading straight for the pair of us who had to leap into separate snowdrifts to avoid being run over.

When we had defrosted afterwards, I went to speak with Mika, and his wife, Erja. It was informal and fun, but I remember her relaying the story of when Mika told Michael Schumacher of his decision to retire from grand prix racing for the first time. Michael, she said, could not believe that Mika would stop when he was at the top of his game, but it was Mika's decision, and he walked away.

Michael stayed on in Formula 1 and, to this day, remains one of the sport's most celebrated drivers. Mika also has a legacy that endures the test of time, being remembered as one of the few capable of beating Michael when the German was at the peak of his power.

## Moving on

After Max Verstappen's fourth successive drivers' championship, sealed in Las Vegas at the end of November, it did curiously remind me of that freezing cold rally, which incidentally was decided by a herd of elk that crossed the road in front of the leader, resulting in his retirement from the event.

Like Häkkinen, Verstappen had said he wants to move on, do other things, and before he set off on his title-winning run, he made time to sit in Acura's ARX-06 sportscar. We know he wants to race at Le Mans, and has already competed in the race in the virtual world. He also has other things he says he wants to do with his life, in racing and outside of it, and seems completely relaxed about the whole situation.

Like Häkkinen, he could walk away from Formula 1 on a high, knowing he has made an indelible mark on the sport. Yet, like Lewis Hamilton, Michael Schumacher, and many others before him, he retains the desire to race, and to win further championships in Formula 1, at least for now.

I have a huge amount of admiration for drivers who can keep hold of that desire, despite such obvious success, but also for those who have the ability to walk away, and to go on to enjoy other forms of racing.

**Red Bull's Max Verstappen secured his fourth F1 World Drivers' Championship at Las Vegas in November. Will there be more to come, or will he follow his ambitions to compete in other forms of motorsport?**

This has been an incredibly competitive year throughout the grid in Formula 1. From Williams, who invested in the future by changing the way it designed and built its chassis, and had a tough season in terms of results (and accidents), to Red Bull, who came up with the best working set-up in the ground-effect era and delivered the drivers' title for Verstappen, to McLaren, that looks set (at time of writing) to win the manufacturers' title. They all can look back on a mighty 2024 campaign.

Winning titles is an enormous feat, considering the complications of bringing a car to the grid in the first place, then developing it – mostly in race conditions as testing is restricted – while also eyeing the next set of regulations. It is a hugely difficult set of circumstances to balance. Just knowing which target to shoot at year on year is hard enough. Teams set their targets, and hope they are good enough even if they hit them.

'Certain expectations we are meeting, that's good,' says Mercedes' Toto Wolff of the 2026 powertrain regulations. 'Others, we're still pushing to achieve our targets. But then the question is, have you set your expectations in the right way? The answer is, we don't know where we are.'

## Strength in numbers

Williams and Red Bull, both featured in this edition, produced a car that was faster this year than last. Even with changes in track conditions, driver line up (Williams) and management (Red Bull), the lap time gain from year to year has been tangible. This is the strength of the teams, both back at base and at the track. The ability to adapt to different circumstances, to take learnings from new data and apply them to making the car faster is what sets F1 teams apart.

So, while I take my hat off to Verstappen on his fourth title, I also raise a glass to the teams that have worked so tirelessly to deliver their drivers the best possible chance to improve. Be it for the world championship, or for valuable (quite literally) points in the constructors' table – which, let's be honest, is the primary driver for everyone midfield and behind – none of the teams have taken their foot off the gas. Consequently, I'm now looking forward to the 2025 season with some enthusiasm.

Can Red Bull and Verstappen stay at the top, or will McLaren 'push to pass'? Can Ferrari get its act together, or is Aston Martin, with Adrian Newey joining its ranks, going to upset the apple cart? Whatever happens, it's going to be good.

**I have a huge amount of admiration for drivers who can keep hold of that desire [to win], but also for those who have the ability to walk away**

# Over the peak

***Red Bull's RB20 has not enjoyed the domination of its predecessors.* Racecar *sat down with the team's technical director, Pierre Waché, to find out why***

**By CHRISTIAN MENATH**

**Waché (left) with Paul Monaghan, chief engineer at Red Bull Racing, on the grid in Australia**

Red Bull Racing has faced tougher competition in 2024 than it did at any other point since the start of Formula 1's ground effect rules in 2022, and the question must be asked: why?

There have been several much-publicised personnel changes at the head of the engineering team, including Adrian Newey to Aston Martin; sporting director Jonathan Wheatley to Audi; head of strategy Will Courtenay to McLaren and chief engineering officer Rob Marshall also to McLaren. These may not have had a direct impact on the season, but surely will not have helped.

The truth is that, while other teams struggled initially to understand the new aerodynamic regulations, they have got to grips with them now, and have started to pose a threat at more of the races. This has put Red Bull on the defensive, particularly as some of the other solutions have produced a faster car. Red Bull knew this would happen; the only surprise was that it took so long for the other teams to tame ground effect.

Coupled with marked improvement from its rivals, the 2024 season has seen some notable dips in form for Red Bull. A winless streak through the middle of the season, just as McLaren found its stride, placed it on the back foot in the constructors' title race.

**'The biggest problem you have with the current rules is that they push you to drive very stiff and have no compliance in the system. As a pure suspension engineer, you don't like this weighting'**

*Pierre Waché, technical director at Red Bull*

As it sought to redress the balance, the team knew it would be a big ask as it would require taking a strong car that was capable at a wide range of circuits and replacing it with another, which was to cope with the ground effect in a very different way.

Red Bull brought many updates to the RB20 during the season (see box out on p10), some circuit specific, others for overall performance gain, but not all hit their target.

## Family tree

It's worth noting here that the RB20 is an evolution of the RB18, which dominated the 2022 season with a 77 per cent win rate, and the RB19, which did likewise in 2023 with a 95 per cent win rate. The aero concept is similar through the family tree, though everything has been optimised for each season's rule set. Consequently, there is, according to technical director Pierre Waché, very little carry over from one car to another.

The first iteration of the car famously carried extra weight, which was shed in the RB19. There were also low-speed handling issues that had to be addressed, and the team admits it is still working to rectify that issue.

'The basic philosophy is the same [between the cars],' comments Waché. 'Even though the bodywork is different, its main purpose is still the same. The rear suspension has a similar concept too, but is just pushed a bit more to the limit.'

The ground-effect phenomenon that captured all the headlines when it arrived was understood better, and faster, by Red Bull than any other team. Where its competitors struggled to cope with the so-called porpoising effect – where the underfloor is starved of airflow when the car is sucked too close to the track, only to then rise again quickly when it loses that suction – Red Bull avoided it by setting its car up differently. Controlling this unwelcome side effect has been the name of the game since 2022.

'The rules actually force you to set the ride height low with a ground effect floor,' says Waché. 'Our philosophy was to make sure the maximum potential of the car is not at the minimum ride height to give us the same opportunity to tune and balance it. It was also about having performance at lower speeds.

'If you do what the rules push you to do – and I think that was done at the beginning – then it's a natural effect that you have a very, very stiff set-up that drives close to the ground. This creates problems with bouncing and, on top of that, it creates problems when you want to balance the car because you have no movement in the suspension.'

Red Bull chose to accept the compromise of having a softer suspension set-up, despite knowing the stiff set-up would produce a faster car if it could be tamed. Having found the range that suited the car relatively early in the RB20's development, the goal then became to make it work at as many different track configurations, and in as many weather conditions, as possible.

This came at the cost of peak performance, and is primarily where the other teams have caught up since. They chose to stay with the stiff suspension philosophy, knowing that when they did manage to tame it, they would have the quicker solution. Red Bull was aware of that, too.

## Soft focus

So, while other teams focused their efforts on making extreme stiffness work, Red Bull went the opposite way and reaped the rewards for its choice. 'It didn't matter if we had 20 or 30 points less downforce, [but] now the people who had those problems can control them,' explains Waché. 'They have learnt from it. We were a bit behind there because our car was set up much softer than theirs. Now we're going in their direction because the performance is there, when you can control the stiffness so close to the ground.'

Red Bull had long been vocal about the likelihood of others catching up, saying it expected tougher competition, particularly from Mercedes in 2023, and McLaren in 2024. However, its competitors' rates of progress, or lack thereof, surprised the team's engineers.

Meanwhile, Red Bull brought updates to the RB20, but did not expect to enjoy the dominance it had in the previous two seasons.

**Red Bull brought a series of upgrades to the Hungaroring in July, including a new front wing, shown here during practice with sensors and in race guise, but it didn't translate into winning form**

**Waché says the RB20's suspension is an evolution of that used on the RB18 and 19, but there are some problems with it**

**'The rules and aerodynamic concept push you to have kinematics that are a compromise between what you want from the suspension and what the aerodynamicists want… it's always a compromise for what's most important'**

*Pierre Waché*

Indeed, that has been the case. It is therefore no surprise to the group that, at time of writing, it is lagging behind McLaren in this year's thrilling manufacturers' title chase.

However, it was in the lead up to August's compulsory summer shutdown that alarm bells really started to ring in Red Bull's design studios. Max Verstappen won in Spain at the end of June but, after an update kit introduced in Hungary in July, the team didn't have another win until Brazil in November. That's not to say the car was uncompetitive throughout the intervening period, but the results were far from what team was used to.

That update included a new engine cover, new front wing, adjustments to the halo, a new profile to the lower front wishbone and rear wheel wrap-around. The engine cover update offered more cooling efficiency in high ambient temperatures, while the changes to the rear bodywork around the wheel improved brake and caliper cooling intake pressures. The front wishbone change increased pressure downstream, while the front wing carried more load without affecting flow stability.

**Waché talks with Red Bull driver, Max Verstappen, who won in Spain in June, but then not again until the Brazilian Grand Prix in November**

'The overall performance of the car [after the update] was poor,' admits Waché. 'It was clear we didn't understand the problem, and didn't know how to solve it [though] we understood it better in Monza.'

## Problem child

'Before you understand an aerodynamic problem, you first have to understand what characteristic you want to achieve. Right from the start of the season, we saw characteristics that were not nice. In the end, Monza highlighted these because it completely destroyed performance. When you drive with very low downforce, the characteristics become even more apparent, and even more important.'

To mitigate this, the team found a different aero balance, but there were other factors at play. Mechanical grip is also key to overall performance, and how any team uses the suspension can vary with different results.

'You have multiple ways to use the suspension,' says Waché. 'On the one hand, you can use it to increase the potential of the tyre, but that is only one of the functions. You can also use it to operate the aero map in the best possible way. And it should also provide good damping to reduce oscillation. The difficulty is to balance and weight these three elements correctly.

'The biggest problem you have with the current rules is that they push you to drive very stiff and have no compliance in the system. As a pure suspension engineer, you don't like this weighting. The rules and aerodynamic concept push you to have kinematics that are a compromise between what you want from the suspension and what the aerodynamicists want. All the positions of the legs have such a big effect on aero performance that it's always a compromise for what's most important.'

Waché admits the RB20 has some suspension issues, and says the team is working to improve them for next season. Whether or not it has done so will only become apparent when at testing for the new season. Even then, it will all be relative to the opposition. Red Bull can only focus on its own car and hope it has improved enough.

## Taking liberties

Right now, the team is focused on low-speed aerodynamic performance, which ultimately will help in the braking phase and on corner entry. That, in turn, means it is looking at ground clearance at the front, and here the old story of aero elasticity comes into play.

**Described in the press as one of the great drives of the modern Formula 1 era, Verstappen put in an incredible performance in the wet in Brazil, proving the car is still both quick and competitive**

Other teams have caught up to Red Bull in terms of ride control so, even with the mid-season aero upgrade package, the Red Bulls have had to fight hard for podium positions

**'Perhaps the others have simply done a very good job. Because you mustn't forget, we are much faster in every race than last year. If we took last year's car, we would be at the back of the grid'**

*Pierre Waché*

There is, says Waché, always a degree of that due to the high loads experienced, but clearly all teams, including Red Bull and McLaren, have taken some liberties here.

'If you have aero elasticity on the front wing, it gives you the possibility to have a lot less load at the end of the straight,' he says. 'Then you can go down with the car for low speed. It gives you the ability to balance the car in a different way, between high-speed and low-speed corners.'

## Snowball effect

All that said, the RB20 is still a faster car than the RB19 it replaced. 'It's clear that if you try to be peakier in terms of characteristics and extract most performance, you pay the price in race trim,' says Waché. 'By definition, your race operation is a bigger window than the qualifying operation. It gives you less room to have an overslide and it's a snowball effect. You overslide even more compared to having a smoother, less peaky map, and then you pay the price over the race distance.

'Perhaps the others have simply done a very good job. Because you mustn't forget, we are much faster in every race than last year. If we took last year's car, we would be at the back of the grid.'

It's clear to anyone watching that the field has closed up dramatically in the last three years, to the point that teams are chasing that last per cent at every race in order to not fall back through the pack. 'The entire field is separated by maybe a second today,' notes Waché. 'With lap times of 75 or 80 seconds, that's a delta of 1.5 per cent. If your aerodynamic delta between two cars is half a per cent, that's the difference between the midfield and the front. That's the delta at which people talk about a good car or a bad car.'

## Red Bull's season in upgrades

As might be expected from a team fighting to keep its champion status, Red Bull was one of the most active when it came to issuing aerodynamic updates to its 2024 car. Over the course of the year, it brought a total of 42 declared components, that is new or modified parts, either performance, reliability or circuit-specific attributes, that must be shared with the FIA.

When a performance update is introduced, it is typically about driving gains in overall car concept, increasing its capability at different tracks, so is usually the most significant type of update. Red Bull's first performance package came ahead of round four in Japan. A new inlet was placed on top of the sidepod, while outlets behind the cockpit were closed off, all with the aim of improving radiator cooling efficiency and airflow to the rear of the car. The team also made 'subtle surface changes' to the floor to add downforce without compromising stability through the corners.

Three races later, with McLaren now starting to pose a threat, the first European round of the campaign at Imola presented an opportunity to bring four more updates. Again, the floor was involved with the shedding edges of the forward portion of the edge wing re-positioned to extract locally more load whilst maintaining flow stability. Red Bull also brought a new front wing, with the leading edge of its end plates re-positioned and the flaps re-designed to extend the chord (the distance between the wing's leading and trailing edges) for added load.

The latter stages of the European leg of the season proved a busy time for Red Bull as the team brought performance-related updates to four races. This barrage of developments included revised rear wing end plates and beam wing elements in Spain, slight re-profiling of the floor edge and body in the UK, a new front wing and revised front lower wishbone profile in Hungary, and a revised rearward halo fairing in The Netherlands. Some of these, especially the Spain updates, were made to add yet more load, while others sought to condition airflow around the car.

Later in the 2024 campaign, Red Bull issued only single-component packages in Azerbaijan (revised floor venturi tunnel geometry), Austin (changes to floor edge camber) and Las Vegas (elevated upper edge of a floor fence to encourage a vortex).

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# Grove's long road

*Williams spent a large chunk of the F1 season trying to shed weight. Now that has been achieved, can it move further up the grid?*

**By DANIEL LLOYD**

Williams unveiled its 2024 car later than the other Formula 1 teams. The FW46 only emerged on track one day before pre-season testing commenced. Meanwhile, its competitors had time to plan and execute elaborate presentations.

Unfortunately for the Grove, UK-based squad, there is no such thing as fashionably late in F1. Its tardy arrival indicated the team had rushed to make the car ready, and gave the ominous impression it would struggle to improve on its commendable seventh place in the 2023 constructors' championship.

As the season progressed, that impression rang true as Williams contended for more than half the season with an overweight car. By the time it had reached the same race weight as its competitors, it was ninth in the 10-team table, and more than 20 points behind seventh. The results improved in the final third of the campaign (spurred by a successful driver swap that introduced the exciting Argentine racer, Franco Colapinto, to the F1 paddock) but Williams' early-season struggles hampered its ability to build on the previous year's progress.

## Worth the weight?

Williams wanted to make the FW46 a more consistent car at a greater range of tracks, even if that meant it would be slower at some of its better circuits. However, reading into that became difficult because the car started the season approximately 15kg over the 798kg minimum weight. This was implicitly revealed by team principal, James Vowles, at the Emilia Romagna Grand Prix, where he said the additional mass was costing 0.45 seconds. The rule of thumb in F1 is that 10kg is worth around 0.3s per lap.

In the FW46's case, being overweight was an outcome of Williams rushing parts of its car design. A cruel twist was that a weight-saving programme for the carbon fibre monocoque, introducted for the FW46, triggered this urgency. Williams' facilities are known to have slipped behind other teams, as exemplified by Vowles this year when he famously scorned the use of Microsoft Excel for a parts list. The team has been working to address

**Williams wanted to make the FW46 a more consistent car at a greater range of tracks, even if that meant it would be slower at some of its better circuits**

some of its obsolete working methods, while in the summer it announced several key hires including ex-Alpine technical director, Matt Harman, and Ferrari's head of performance analytics, Fabrice Moncade. However, its bold chassis weight-saving endeavour stretched other aspects of car development to the limit.

'With hindsight, we just squeezed the design time for quite a few of the parts too much,' says Dave Robson, head of vehicle performance at Williams Racing. 'We put a lot of effort into taking weight – ironically – out of the chassis. That was as much to do with learning how to manufacture the chassis and design it in a slightly different way, to take a fairly sizeable weight saving. That is technology and experience that will pay us back over the coming years, so there was a clear and conscious investment of time and effort into the chassis.

'However, that had the initially unintended consequence of pushing the design time on other parts that team of engineers was responsible for designing.'

The FW46 was overweight in a range of areas, including major components such as the front and rear wings, the floor and some suspension parts. The cumulative effect of this gave Williams its priority for the first half of the season: bring the weight down to 798kg.

'There wasn't the capacity within the design department to do the number of iterations we would have normally done to take the weight out,' adds Robson. 'You end up just being left having to make all of those parts safe and reliable at the cost of weight, and worry later about how you come back to do new iterations of them.' A heavier car

**A heavier car was the price Williams paid for focusing on making its monocoque lighter**

was the price Williams paid for focusing on making its monocoque lighter. Robson won't disclose exactly how much weight the team shed from the FW45 monocoque to the FW46, but acknowledges it was 'similar' to the amount that needed to be removed from other areas. So, the rush to get the car ready not only ate into the margin Williams gained through a lighter monocoque, but also tipped the FW46 into overweight territory.

## Slimming down

The FW46's debut in Bahrain concluded with Alex Albon finishing 15th and Logan Sargeant 20th, both lapped. There was clearly a long way to go, but there was also opportunity.

'The rear wings got lighter, the floor lighter [and] the roll hoop definitely saved a good amount of weight, particularly given how high up on the car it is,' says Robson. 'A lot of the other bits are a summation of smaller things, a lot of which you can do because we had to make a season's worth of parts anyway. We were able to modify the designs before we'd made that full complement.

'Apart from the design time to work out how to take the weight out of additional structures, and still ensure it's stiff and strong enough, it didn't actually cost us cost cap expense. It's just taken a bit of time through the season for those things to filter through into the prime spec on the two racecars. I think almost all areas of the car, we were able to look at and find some weight saving.'

When Williams finally reached the desired minimum weight, shortly after its major update package at round 15 in The Netherlands, it started to score points more frequently. However, that came too late for an improved championship finish to be realistic. That said, Williams did rise to eighth at one point, only for Alpine's shock double podium at a wet São Paulo GP to drop it back down a peg. Adding to the pain, Williams had three crashes in Brazil, including one for Albon in qualifying that forced his car to be withdrawn.

The question now is whether Williams can avoid having an overweight car in 2025. The team is confident that won't happen because the monocoque weight-saving programme is complete. It also doesn't expect to be under as much time pressure as it was last winter.

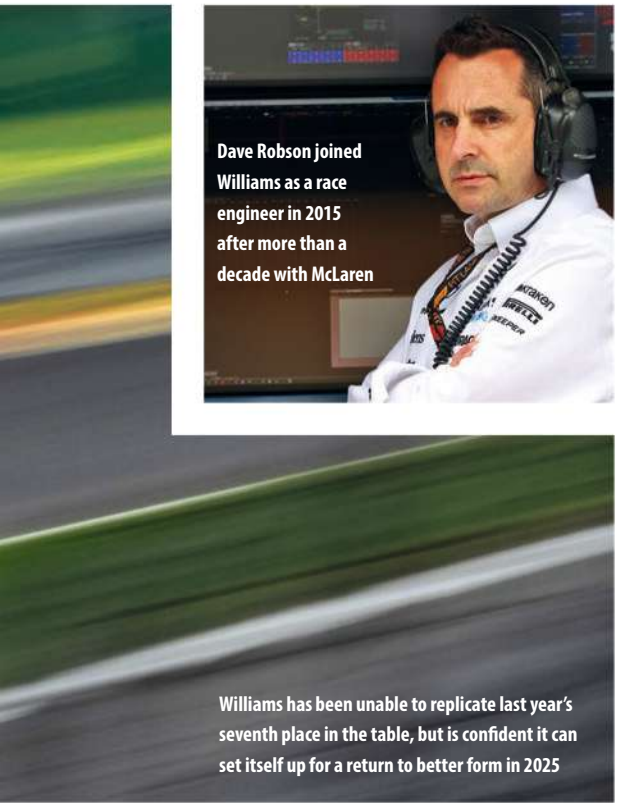
Starting the season at the right weight is likely to give Williams a better chance of scoring points more consistently. In 2023, it reached the top 10 in eight grands prix. With three races to go this year at time of writing, it had only achieved that six times at five races.

'We've had the opportunity from this year's weight-saving programme to identify other opportunities to save weight that we haven't been able to do this year, but we can do on the 2025 car,' says Robson. 'The design on those opportunities is already under way. So, we should start with a lighter underlying mass of the car, and then that gives us a little bit of flexibility if we do choose to leave some of the components in the wind tunnel a bit longer and compress the design cycle.



Dave Robson joined Williams as a race engineer in 2015 after more than a decade with McLaren

The first big problem this year was an overweight car that team principal, James Vowles, said was costing almost half a second per lap



Williams has been unable to replicate last year's seventh place in the table, but is confident it can set itself up for a return to better form in 2025

The intensive focus on shifting weight from the FW46 delayed development of other performant areas of the car until later than planned in the season

That would obviously be different to last year because we would be doing it by choice, for aero performance reasons.

'We will have some mass in hand because, fundamentally, the car will be lighter than this year's car was at the start. There is quite a lot going on that means we won't be in that situation for 2025.'

## Knock-on effects

The time taken to reduce weight in the chassis of the FW46 affected Williams' application of performance upgrades. The team brought smatterings of changes, but these were either part of the car's diet or circuit-specific modifications, such as higher-downforce rear and beam wings and a more potent brake cooling architecture for Monaco. Or a combination of both.

It wasn't until after the halfway stage that its major upgrade arrived, with the target of adding downforce. At Zandvoort, Williams brought five significant changes, designed to work in conjunction with each other to bring a modest lap time gain. The package included a new floor geometry, diffuser, sidepod inlet and outer geometry and a revised roll hoop. The team also modified the monocoque to accommodate the new bodywork.

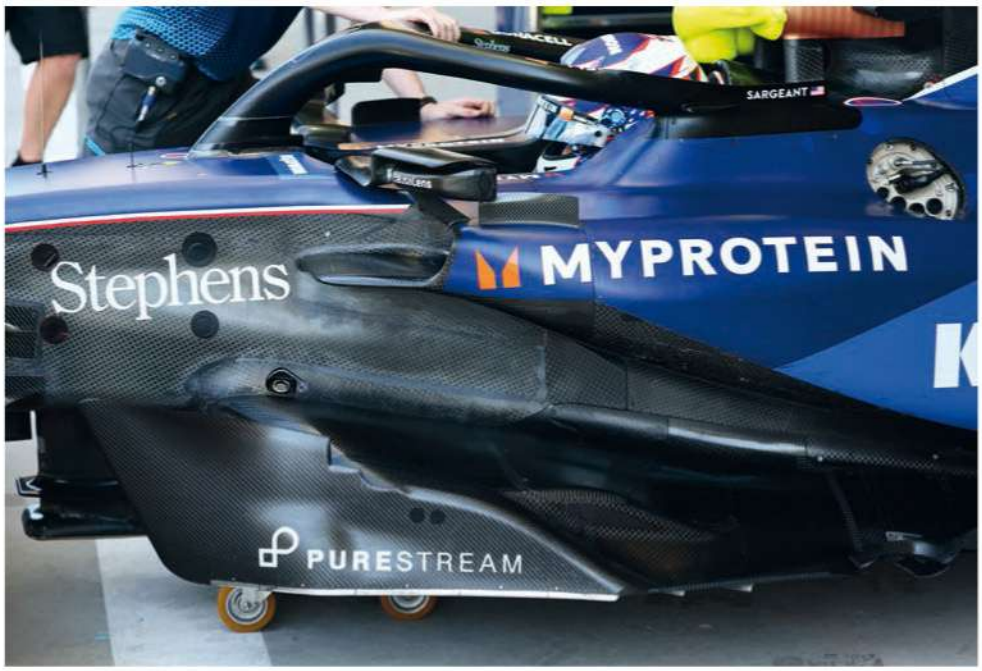
Some of those changes were intended to be introduced earlier in the campaign, but the focus on weight saving pushed things back. There was also the knock-on effect of leaving less time to gather real-world race data that could inform on potential follow-up changes, or development directions for 2025.

'We definitely could, and should, have had it earlier, certainly before the summer break,' acknowledges Robson. 'Probably around Canada time [round nine], which is where we brought the major floor upgrade last year. That is a sensible time to bring it. But we definitely prioritised some of the weight-saving components over the first third of the current season.'

Following the trend set by the likes of Red Bull and McLaren, Williams switched to a sidepod radiator inlet featuring an upper surface longer than its lower surface, rather than the other way around. This is designed to minimise the loss of airflow coming from the front. The wing, meanwhile, is designed to push airflow towards the underfloor and diffuser, two key downforce-generating components.

The structures behind the front wing, such as the sidepod inlet and halo fairing, facilitate the airflow's rearward path. Williams introduced a new geometry for the forward part of the halo shroud in China, which it fitted as and when during the season.

'It's about controlling those flow structures so you get the most out of the diffuser,' says Robson, 'but you've got to be careful you don't then lose that downforce as soon as the




**The FW46's original sidepod inlet pictured at the start of the season. This concept remained until after the season's halfway point**

**The new sidepod inlet introduced as part of a major upgrade package the team rolled out at Zandvoort, featuring a clear 'overbite'**

**The more aggressive floor edge that also appeared at Zandvoort points to upgrades made to the underfloor. Williams sought modest gains from an overall package that worked, rather than pushing for something more that could yield negative side effects**

car is in a yawing state in cornering, or in side winds. You can quickly be up at the centre of the map but, in the real world, the car almost never experiences that for a prolonged period. So you're always trading the robustness of those flow structures against the downforce they generate. That whole sidepod inlet is just setting up the flow for the rest of the sidepod, going rearwards on the car and into the above-diffuser area.'

## Damage control

Accidents also played against Williams in its race to upgrade the car. It has been one of the most crash-prone teams this season. In practice for the Australian GP at Albert Park, Albon crashed hard into the wall at turn two after losing control over a kerb. The damage to his car's monocoque ruled it out for the rest of the weekend. With no spare chassis available, Williams put Albon in Sargeant's car and sat the American driver out of the race.

At the next round in Japan, Sargeant spun nose first into the tyre barriers, giving the mechanics a further headache. Other accidents included a collision between Sargeant and Haas' Kevin Magnussen in Miami, and separate strikes for both cars in the damp in Canada. This all fed into delays on the delivery of upgrades, as focus shifted to repairing and replacing damage, whilst simultaneously trying to sand off the weight.

**Crashes hampered development and Sargeant's massive off in practice at Zandvoort made it hard to judge how successful the upgrades were**

**'The headline number we were expecting as a lap time gain for the Zandvoort upgrade was quite small… [but] we delivered it without any major side effects, and genuinely delivered what we expected'**

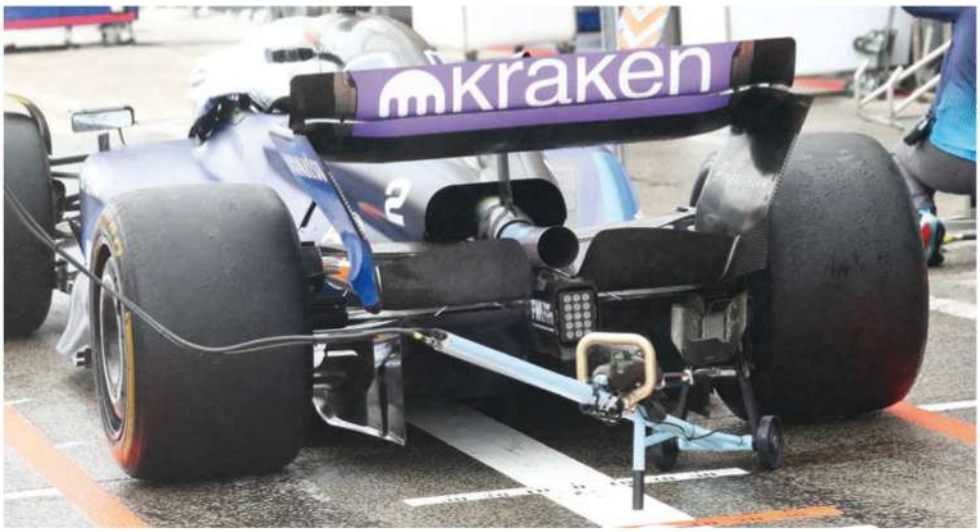
*Dave Robson, head of vehicle performance at Williams Racing*

'The attrition was higher than we allowed for in the initial plans,' admits Robson. 'The wind tunnel work for what became the Zandvoort upgrade was done in good time, but having the time and resources to engineer and deliver it was hampered by the attrition and choosing to focus on the weight saving. At least we knew the weight saving was guaranteed lap time. [With] aerodynamics, even though we were pretty confident with what we were doing, there is always a higher risk with that.'

## Net effect

Williams envisaged the Zandvoort upgrade to be worth two to three tenths of a second. Robson reports the team 'got what we expected', although it took a few races for the gains to become apparent. As subsequent races played out, Williams started to learn what the upgrades were bringing.

Sargeant was sacked after Zandvoort, after another big crash in practice, and replaced with Colapinto, who finished 14th on debut at Monza. Albon finished ninth, only the third Williams points score of the season at that stage. Both drivers then scored points in Azerbaijan, although their scores were boosted by a late collision between Carlos Sainz Jr and Sérgio Perez. Colapinto then earned a further point at Austin.




**A new diffuser was also introduced in Zandvoort, along with modifications to flow paths ahead of it to get the most out of the device**

'You can end up finding that you make the car slower as a result, particularly once you start to increase tyre degradation, for example,' explains Robson. 'Even for the teams with the best possible simulation and tyre models, it's still difficult from the raw wind tunnel output to assess what the net effect across all the remaining races of the year is going to be. I think that's why we see teams struggling.

'You're then faced with asking how greedy, or risk averse, do I want to be? The headline number we were expecting as a lap time gain for the Zandvoort upgrade was quite small, compared to what we would normally consider to be an in-season upgrade. But because we delivered it without any major side effects, and genuinely delivered what we expected, it's actually – in the context of the season and across all the other teams – a fairly good upgrade.'

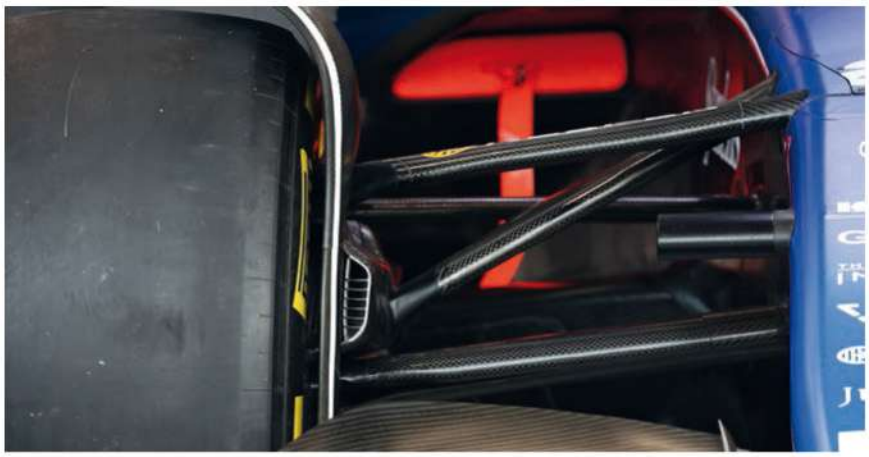
## Measure twice…

Zandvoort was a busy weekend for Williams as Albon was disqualified from qualifying after the FIA discovered the rear part of his car's floor was wider than permitted. Williams said its measurement system gave a different result, but accepted the penalty. After that misstep, the team reviewed its process of measuring the floor to ensure its readings would match the FIA's.

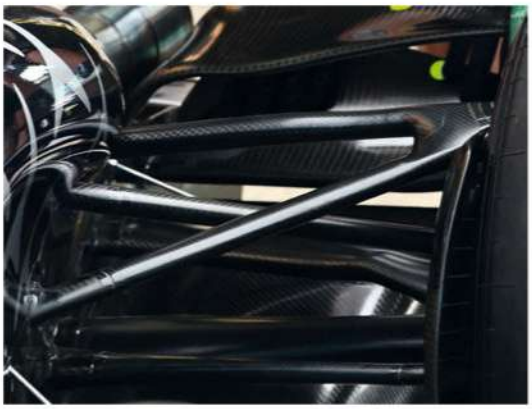
'We've made changes to the way we check those components before they leave the factory,' confirms Robson. 'We have previously relied on checking them at the track but, with all the curfews we have throughout the weekend, it is very difficult to find the time to do that thoroughly. Also, it's true that if you measure the floor in isolation at the factory, the measurements are different to when you bolt it up to the car because of the way it attaches in discreet places. None of that is an excuse, we just should have been doing a better job at the factory to sign it off.'

Robson asserts the wider floor section gave no car performance benefit, which was reflected in there being no major changes to the structure after that race. 'I think, frustratingly, with that particular incident, we saw no lap time gain from doing it at all. That suggests we were being unnecessarily greedy. We could have just made it a millimetre or two inside the regulation box, rather than aiming for half a millimetre, or whatever it was, and it wouldn't have cost us any lap time performance.

'At the same time, you can't allow that kind of attitude to exist on everything, because there are some things that are *very* sensitive. We need to sharpen up the way we measure things in the factory, and make sure every part leaves with its own legality passport, a full sign-off. The reality is you make five or six seemingly identical



Albon's car received new suspension components in Singapore to help balance aerodynamic changes from Zandvoort



Comparison between the pull rod rear suspension of the FW46 (above) and the pushrod rear suspension adopted by Mercedes in 2024 (below)

floors for the next event, but they are all different. You have to check every one of them, and check them correctly.'

The Zandvoort package was the first stage in Williams' application of performance upgrades to the FW46. Albon said at the next race in Italy that further changes would 'tie up the balance problems' he had been feeling, rather than simply adding load. Williams then brought updated front wishbones, track rod and pushrod geometries to his car in Singapore, along with minor updates to brake duct surfaces and chassis leg fairings. Putting both the load and balance aspects of the upgrade suite on at the same event would have delayed their introduction further. After the weight saving and accident issues, Williams couldn't afford to wait any longer, so it brought the modifications in stages.

'The new front suspension shrouding was about setting up the flow onto the parts we upgraded in Zandvoort,' says Robson. 'That's a final step, tidying the flow as it arrives to the sidepod area. With that, we can use those changes to ensure we made those flow structure changes more stable, which helps to drive the balance improvement.'

## Universal vision

'There were minor changes to the suspension that allowed us to change the front heave stiffness a little in some slightly different ways. It allowed us to play with the front ride height sensitivity of the aerodynamics to tune the balance. That was the final piece.'

Williams fitted Albon's Singapore upgrades to Colapinto's car at the next round in Austin, where he finished 10th. According to Robson, those updates 'opened up the set-up window' for the race engineers at the later rounds. This helped to address one of Williams' core aims in the second half of the current F1 rules cycle since 2022, which has been to deploy a more 'universal' machine that is adaptable to different circuit layouts. In the last few seasons, the team has typically produced cars

**'We wanted to make sure we had the best possible correlation to the wind tunnel, and try to improve our understanding of how we're prepared to trade downforce improvements for characteristics'**

*Dave Robson*

that are strong in low-drag scenarios, but lose momentum in the corners relative to others.

'It's fair to say that, for the FW46, and on into the FW47 for next year, we're using those two cars to change the way we work, with a view to putting ourselves into a better position for 2026 and beyond,' explains Robson. 'What we tried to do for this year was make it a much more universal car. Previously, we had been guilty of being reasonably good at some circuits, but at the expense of others.

'Maybe it becomes a bit of a self-fulfilling prophecy but, if you don't expect the car to be that competitive, if you want to try and pick up some important points by targeting some races, that is a strategy, though clearly not one that is ultimately going to win you championships or be very robust for the future. It was a deliberate effort for the '46 to change that and make it much more of a 'go anywhere' kind of car.'

The final season of the current rules cycle next year will identify whether Williams' approach has been effective. It may also come in the context of a different suspension layout. The FW46 used the 2023 gearbox and rear pull rod arrangement of Mercedes, its power unit supplier. Although unconfirmed until it rolls out, next year's Williams could feature pushrod rear suspension connected to this year's Mercedes gearbox. Mercedes and customer team, Aston Martin, adopted the pushrod in 2024, but Mercedes couldn't guarantee enough new 'boxes for both Aston and Williams, so the former was given priority.

Robson is confident Williams has made the FW46 more versatile. Evidence of that has been hard to gauge, since most races after Zandvoort offered different conditions to last year. There was also the fact Williams had a different driver in one of its cars, muddying the figures. Singapore may have been a useful comparison, but Albon retired after 15 laps due to a power unit cooling issue. However, in qualiying at Austin, he was 0.881s quicker through the twisty final sector than in 2023. Everybody improved, in part due to a fresh track surface, but Albon's year-on-year step was greater than all but two of the drivers.

'The car was much better across a range of different cornering types,' suggests Robson. 'That's been pretty successful. The other thing that was important was we wanted to make sure we had the best possible correlation to the wind tunnel, and try to improve our understanding of how we're prepared to trade downforce improvements for characteristics. I think some of the updates we brought to Zandvoort did what we expected; I'm not sure all the teams always found that.

'We were determined we were going to make the car quicker by the amount we expected, based on the wind tunnel. Pretty much, we did that, which is good for the FW46 programme, but also for the '47 and subsequent programmes.'

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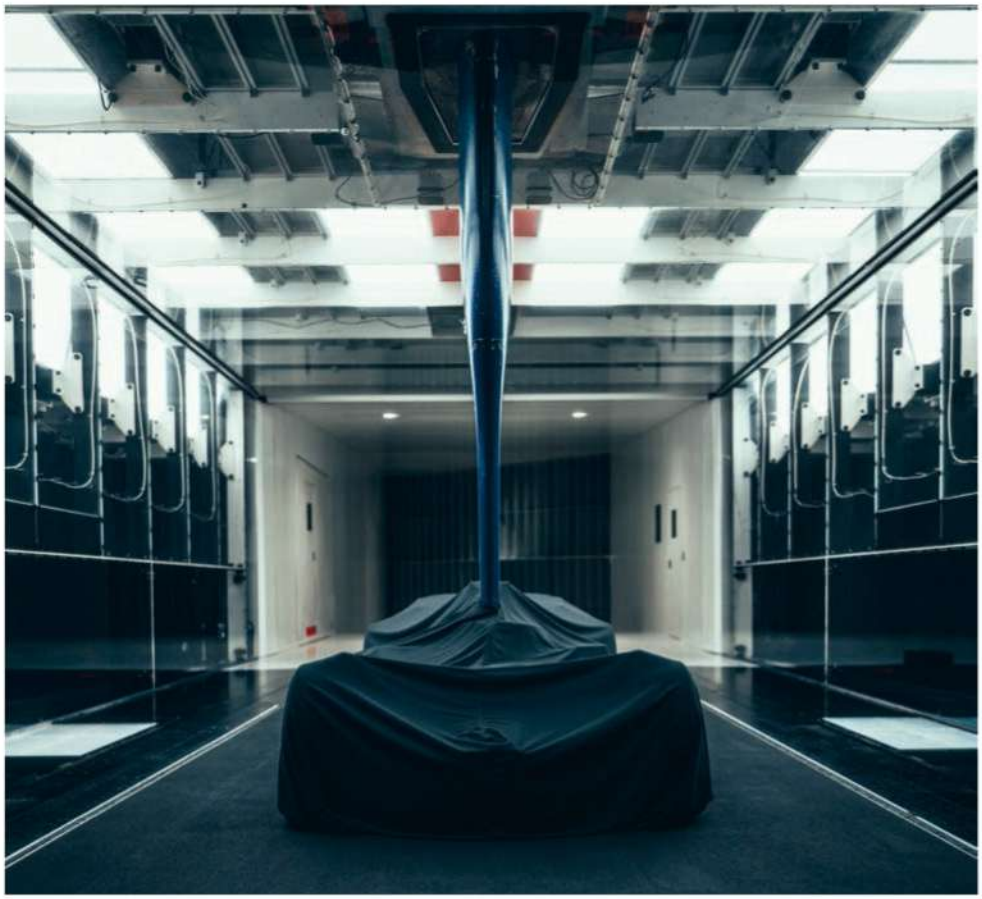
# Second coming

*Williams Grand Prix Technologies was launched this year, commercialising the F1 team's expertise with AI and machine learning at its core*

**By DANIEL LLOYD**



WGPT

**On the face of it, WGPT may appear similar to companies that came before it, notably Williams Advanced Engineering (WAE), but this is an entirely new applied engineering venture from the Formula 1 team's current owner, Dorilton Capital**

In 2010, the management group behind the Williams Formula 1 team set up a company to commercialise its engineering capabilities. In 2024, the management group behind the Williams Formula 1 team set up a company to commercialise its engineering capabilities.

On the face of it, history appears to be repeating itself. However, the newly formed Williams Grand Prix Technologies (WGPT) is a new and different proposition to its predecessor, focusing on distinctive technologies for evolving times.

Launched in April, WGPT is a sister company to Williams Grand Prix Engineering, which is the official name of Williams F1. It has its own management board and is based at the same campus as the F1 outfit at Grove in Oxfordshire, UK. WGPT has proposed a range of services, including platform dynamics, advanced materials, simulation and data analytics, all drawing on technology first applied in motorsport. The deployment of these solutions is underpinned by a strong focus on using artificial intelligence (AI) and advanced machine learning.

The target audience is deliberately broad, and so far the company has generated interest from the defence, marine, leisure, aerospace and automotive sectors.

At its core, WGPT aims to bring F1 engineering expertise to the wider world. This concept is not new. McLaren and Red Bull founded their own applied technology firms in 1991 and 2014 respectively. Williams, of course, did it once already in 2010 with Williams Advanced Engineering (WAE). Many other motorsport companies outside of F1 have also successfully commercialised their equipment and methods, with the collective selling point of being able to meet tight deadlines that other industries cannot match.

WGPT is hoping to put its own spin on the genre with its implementation of AI tools. It also has a head start because it can use the name of F1's second most successful team. Operating under the Williams banner helps to give WGPT a certain status – a heritage of innovation on which to build its future.

## Historical context

To understand why WGPT has been created, it is important to note the historical context. The Williams F1 team was established in 1977 by Sir Patrick Head and Sir Frank Williams. To date, it has won nine constructors' titles, seven drivers' championships and 114 grands prix, most recently 12 years ago.

In 2008, the team launched its first engineering offshoot company. Williams Hybrid Power (WHP) was set up to develop and market a flywheel kinetic energy recovery system (KERS). The innovative technology was first explored by Equipmake, whose founder, Ian Foley, set up Automotive Hybrid Power in 2006, re-naming it as WHP when Williams bought into the business. The flywheel was used in the 24 Hours of Le Mans-winning Audi R18 e-tron quattro and the Porsche 911 GT3 R Hybrid, as well as in hybrid-powered buses for the road. WHP was sold to GKN in 2014.

In 2010, a more sustained expansion into wider industry was made, as Williams established its next commercial engineering branch, WAE. The company has specialised in electric powertrain technologies, including high-voltage batteries, and was sold last year to the Australian mining giant, Fortescue, in a deal worth £164 million (around $213 million at the time). It was re-named Fortescue Zero, demonstrating its positioning as the parent firm's sustainable technology lab.

In motorsport, WAE has supplied battery packs to the likes of Formula E and LMDh, and has also applied its expertise to other industries such as automotive, defence, commercial vehicles and rail, which is part of the reason why Fortescue invested.

## Fresh investment

The sale of WAE to Fortescue came two years after the Williams family relinquished control of the main business in a sale to Dorilton Capital, a US-based private investment firm. With WAE leaving the group, and WHP a distant memory, a hole emerged in Williams'

WGPT

**F1's cost cap meant Williams had engineering facilities it wasn't utilising to its fullest, which is where WGPT steps in**

WGPT

**AI and machine learning will underpin all activities at WGPT. Their use in speeding up simulation and physical testing is something the company wants to harness for customers in sectors reaching far beyond just motorsport**

output beyond F1. Dorilton came in with fresh investment aimed at returning an ailing race team back to prominence. Now, it is also delivering the resources to bring applied engineering back into the Williams organisation.

'Williams Grand Prix Technologies started on the back of the new investment group taking over Williams, which is trying to bring Williams Racing to the front of the grid,' says Selin Tur, chief technical officer and managing director of WGPT, 'and also utilising the Williams brand in wider sectors, to have a high outreach. There are multiple reasons for that. The team has some valuable assets but, due to the cost cap regulations, it cannot utilise them at full capacity. WGPT allows us to utilise those assets and create new revenue streams for the group.'

The first six months of WGPT's existence have focused on advertising what it will offer, although some client work has already been undertaken. The company has a three-year plan for its initial growth, which involves establishing strong foundations in its core fields and increasing the full-time staff count.

Despite starting off in single digits of employees, WGPT has ramped up its recruitment of key engineering positions as 2024 has progressed. Roles filled have included departmental directors of aerodynamics and electronic systems, and senior engineers for control systems, machine learning and simulation.

'We are a small organisation going through a set-up process,' explains Tur. 'We are hiring seven engineers at this point in time, including programme managers and technical assistants. We have internal engineers and consultants working with us already, and are being supported by our wider engineering skills across the group. We will be growing over time; we have approval for hiring resources next year.'

WGPT cannot disclose the clients it has been working with so far due to confidentiality agreements, but it has been active. Just 10 days after the company was established, it received the call from a global defence and security engineering firm to develop a prototype part for a feasibility

**'The [F1] team has some valuable assets but, due to the regulations, it cannot utilise them at full capacity. WGPT allows us to utilise those assets and create new revenue streams for the group'**

*Selin Tur, chief technical officer and managing director at WGPT*

study in under three weeks. It met the brief in 18 days, modifying the part's design with a different moulding technique and testing it before delivering to the customer.

'When it comes to non-racing clients, our speciality becomes the rate of speed that we can respond to their requirements,' indicates Tur. 'It could be a lightweight material development for a specific client, which would normally take months for them to design, develop and prototype. For us, this type of activity is measured in days.'

## Machine learning

Simulation using machine learning is an area in which WGPT hopes to prosper. The F1 team uses JuliaHub, a computing package with modelling and simulation capabilities. This has helped in three main ways. Firstly, it is claimed to have improved the accuracy of aerodynamic models by seven per cent and made the process of creating them 170 times faster. Combining it with tools developed in-house, the software's GPU programming features take air pressure measurements and turn them into models.

Secondly, the simulation software has created a digital twin for a physical sensor, saving weight and reducing aerodynamic disturbance. Williams had used machine learning in the past but updated its methodology with Scientific Machine Learning (SciML), which adds scientific computing techniques into the mix. For the F1 team, this captured high frequencies found in vehicle control inputs and incorporated vehicle motion models. It produced quicker and more accurate results than the standard machine learning tools.

Finally, the AI software helped accelerate Williams' tyre deformation simulations. WGPT now intends to use the JuliaHub package in its offering to clients beyond motorsport.

'All we will do at WGPT will be very much focused on AI, machine learning, digital twins and data analytics,' confirms Tur. 'This is going to take us some time, but we have a number of partnerships. We have been working with JuliaHub developing scientific machine learning-assisted technologies. For example,

replacing some of our physical sensors with machine learning models based on other sensors we have on the car. We will gradually increase the integration of machine learning into the design, development, testing and analytics processes.'

## Differences to WAE

WGPT wants to avoid comparisons with WAE, preferring to focus on its own journey. But it's also important to avoid confusion between the two, especially as the latter has changed its name multiple times and is no longer part of the Williams group. Tur is well positioned to identify the differences as she was a high-ranking engineer at WAE for several years before returning to Grove at the helm of the new company (see box out below).

'In the previous organisation, the focus was predominantly on battery electrification and prototype vehicle applications,' she explains. 'WGPT is looking to utilise core F1 technologies and integrating the advanced technologies on top of it, providing advanced service offerings, heavily integrating machine learning and data analytics. So we will not be building prototypes; we will be focusing on customers' challenges and finding solutions around that, using advanced technologies. It doesn't preclude us from making final products, but we will be working with our partnerships and supplier bases to address those challenges, rather than doing it here.'

That is a key difference between WGPT and WAE, which has been successful in developing electric powertrain components with its partners. According to Tur, who helped develop WAE's first Formula E battery in 2013, manufacturing and single supply contracts are not avenues WGPT is actively pursuing.

'The world is full of batteries,' says Tur. 'The world, and technology, have changed. Our focus will not be on electrification. We will evaluate the opportunities, and potentially support business that wish to win those kinds of contracts and have done excellent designs, coming up with better cooling systems, utilising machine learning and advanced simulation techniques. We will support their design, development and manufacturing journey, providing the services necessary.'

For instance, instead of designing and manufacturing an electric motor or battery, WGPT might advise a battery manufacturer on how to make it lighter and more efficient.

## Space sharing

WGPT shares the F1 team's facilities, borrowing time at different stations depending on availability and the job at hand. It has already worked with some motorsport customers on testing mechanical systems, structural parts and suspension layouts. WGPT also has access to both Grove wind tunnels, for customers to test the aerodynamic efficiency of parts. F1's restrictions on the number of wind tunnel tests each team may carry out eases pressure here on time sharing.

WGPT

**The green fields of Grove in Oxfordshire, UK, home to the Williams Formula 1 team now for 28 years. It moved there during the 1996 season, taking with it a 165-tonne wind tunnel. WGPT will operate out of the same site**

WGPT also has access to an array of testing facilities, including 100kN hydraulic single axis dynamic test rigs, a single 40kN rig and a damper dyno rig with a 25kN high response actuator. There is also an eight-post rig with four 35kN displacement actuators and four 20kN aerodynamic load actuators, a 400kN modular chassis rig for static and homologation testing, a brake cooling efficiency rig and a gearbox articulation rig.

'This requires a lot of close working and planning,' notes Tur. 'We have very detailed resource planning groups at our racing site, not only about engineering resources, but about timing. Working with the customer and understanding their requirements, we go into how we can schedule this into existing activities around the F1 team's development.'

There could be future opportunities for infrastructure expansion, too. Last year, Fortescue opened a new headquarters and battery manufacturing plant near Oxford Airport and announced the construction of a new 13,500m$^2$ factory for off-road vehicles in Banbury. WAE then fully vacated Grove in April, moving to Oxford Airport. It left behind a 3,800m$^2$ R&D facility, which was built at a cost of £8 million and opened in 2014.

'We have an ongoing investigation on how we will utilise the existing campus,' says Tur. 'It is not specifically for WPGT or Williams Grand Prix Engineering, but for the entire [site]. There is nothing I can confirm regarding which direction we will go in, other than we are going through a transformation journey with our existing facilities, updating them, making some moves around and focusing on potential future investment across campus.'

With Dorilton's backing and a rich F1 heritage to lean on, WGPT is positioned to enter the applied engineering market at full steam. Williams has already proved it can be successful in this area with WAE; it now has a chance to do it again with new owners, different technologies and fresh ideas.

## Personal journey

**Selin Tur is at the helm of WGPT's genesis. For an engineer whose career has focused heavily on developing electrified propulsion systems, being able to lead a new type of applied motorsport technology company is a huge personal milestone.**

**Born and educated in Turkey, and inspired by the UK's motorsport opportunities, Tur moved to Britain in the late 2000s. After a brief period working for AVL in its transmission and hybrid department, she was headhunted by Mercedes-AMG High Performance Powertrains. There, Tur helped design and develop battery electronics for the KERS system that appeared on the McLaren MP4-24, the first car to win a race using such technology. She went on to join WAE in 2011 as a technical leader for its electric propulsion components, including the Jaguar CX75 hybrid road car and the first-generation Formula E battery.**

**In late 2015, Tur was seconded to the Jaguar Formula E squad to lead development of one of the series' first powertrains to be developed in-house by a team. Her affiliation with WAE ended in 2018 and, after a spell working outside motorsport as a technical manager in the commercial vehicle sector, Tur has now returned to Grove.**

**'I've been lucky enough to ride one of the fundamental, transformation technologies with electrification,' she says. 'I believe it is in the application and implementation phase, and there is a new generation of technology here, which is fundamentally driven by AI and machine learning. I have been given an opportunity to lead that journey. From a personal level, there are not many roles that can replicate what I'm doing right now, and that's incredible for me.'**

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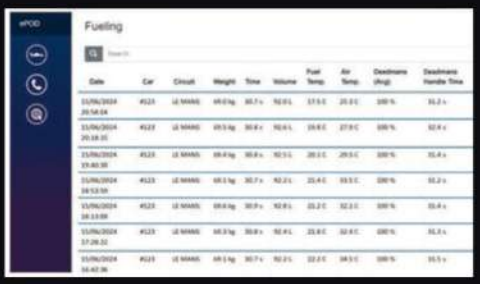


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# Mixed fortunes

*Ferrari, Toyota and Peugeot had different challenges to face in WEC this year.* Racecar *assesses how the LMH manufacturers got on*

**By ANDREW COTTON**

LMDh cars outnumbered LMHs in the WEC for the first time this year, but Toyota still managed to defend the manufacturers' title and Ferrari won at Le Mans. A Porsche crew earned the drivers' championship aboard an LMDh

On paper, the fortunes of the three LMH cars that ran the full FIA World Endurance Championship season in 2024 echoed those of the previous year. Ferrari successfully defended its 24 Hours of Le Mans victory and Toyota secured the manufacturers' title, while Peugeot was again out of contention for accolades, even with a heavily altered version of its 9X8.

But despite their season outcomes being similar, each of those LMH factory teams (plus Ferrari's satellite squad) had to battle different issues throughout the eight-race campaign.

Toyota was hit at the beginning with a huge weight increase courtesy of the Balance of Performance system. The GR010 Hybrid was set at 1089kg, exceeding the previously stated, crash tested, minimum of 1080kg. The extra weight told immediately at the opening race in Qatar. Tyre degradation was higher than the team had ever experienced, and so the advantage the GR010 had always enjoyed – better performance at the end of a second stint on a set of tyres – was negated.

For Ferrari, a new, so-called two-stage BoP system was introduced for Le Mans, where power over 250km/h was adjusted to reduce the disproportionate advantage enjoyed by the 499P, particularly at a track with such long straights. The Italian marque then introduced a new brake package for round five in Brazil, where it was firmly trounced by Toyota.

Peugeot finally stepped away from the wingless concept for its 9X8 in time for the second race at Imola, but the new 'Evo' car didn't perform as hoped. Operationally, the team improved to a point that it was making ground during races through good pit work, but there were still fundamental issues with the car inherited from the previous version.

## Development scope

Other than Peugeot, upgrades made to the LMHs this year have been minimal by design, to try and limit cost escalation. These restrictions will stay in place for the rest of the LMH rule cycle which expires after 2029.

Development of cars in the WEC's Hypercar class, whether LMH or LMDh, is actively discouraged by regulation (the primary function of BoP is to reduce the need to keep updating cars), unless there is a package introduced to improve reliability, or performance. The latter is restricted in number, the former is not, but whether teams are allowed to modify their cars, and how that upgrade is judged, is at the behest of WEC organisers the FIA and ACO. Teams submit a request to bring a performance 'joker' upgrade, and it is then down to the governing bodies to decide what effect that will have.

Naturally, the biggest topic in the paddock over 2024 was – or would be if teams were allowed to speak of it – the BoP. Teams have been banned from talking about specific BoP decisions for some years now, but the topic is now ruled as taboo under all circumstances.

For the series, it was clear that in order to stay ahead of the competition, it had to keep the BoP criteria it was looking at secret to avoid teams playing the game better.

The result was the racing was good, and the balance was clearly effective overall, but

**Naturally, the biggest topic in the paddock over 2024 was - or would be if the teams were allowed to speak of it - the BoP**

The wingless Peugeot 9X8 made its last showing in Qatar before being replaced by a more conventional concept

there are still glaring holes in the system, and the manufacturers have raised concerns.

The BoP balances weight, power and aero efficiency, but does not take into account braking, notably the braking effect of the power unit with the different engine configurations, traction control and turbo lag.

It also doesn't account for suspension set-up, which helps with squat, dive and mid-corner speed, nor the effect of a hybrid system working full time on the rear axle, which only the LMDh cars do. The LMH hybrid deployment is set through the BoP and has stood at 190km/h for all cars since Imola.

Manufacturers have stated that without all these items being considered, there is a whole new area of the circuit that can be exploited to gain lap time, going so far as suggesting they may have to build their cars differently to maximise this potential. Far from being a cost-saving measure, they argue, this could be one of the most expensive side effects of performance-balanced racing.

## Toyota GR010 Hybrid

Clearly, Toyota's GR010 was the fastest car in 2023, so there was no hope of the Japanese manufacturer being granted permission to introduce an update package for performance. The team didn't feel the need to apply for any reliability upgrades, either, as the 2023 season also proved there was no issue on that front.

For 2024, therefore, its car was running in largely the same guise as the previous season, though the team did have to take steps to adapt to the additional BoP weight. It also had to evolve its race strategy to cope with increased tyre wear, and did so primarily by avoiding double stinting all four tyres at the same time where possible. That also reduced the issue of warming up the tyres without pre-heaters, which are banned. Changing tyres only on one side achieved the same goal, with less time lost on out laps, while at the same time reducing time loss on old tyres.

At the high weight, the Toyota was able to produce a good lap time in qualifying on nearly empty tanks, but on full tanks, and with a double stint required due to the number of tyres allocated per race, the team had clearly lost its usual performance advantage by the end of the second stint.

'It is very difficult to simulate accurately the tyre behaviour on the different tracks and, when there is a big weight difference between the cars, it is not necessarily easy,' says Toyota WEC technical director, David Floury, who moved into the role in place of Pascal Vasselon in January 2024.

Toyota struggled throughout the year, though the weight did decrease, to 1070kg, by the final race of the season in Bahrain. By then, Toyota had only won at Imola and São

Toyota had to adapt its pit strategy because of increased tyre wear, but made all the right calls in the rain at Imola

**The racing was good, and the balance [of performance] was clearly effective overall, but there are still glaring holes in the system, and the manufacturers have raised concerns**

Paulo. In Bahrain, it was able to maximise its tyre strategy and, at two separate points in the race, Sebastien Buemi made up more than 20 seconds on the leader. There was clearly performance in the car when needed.

When Toyota won at Imola in May, it did so by making better strategic decisions than Ferrari, rather than being faster. Ferrari took the top spots in qualifying, and was on course to sweep the podium before rain hit.

'They were faster than us in every area, except strategy,' said Floury after the race.

Toyota also won the 6 Hours of São Paulo, where again it out-boxed the opposition on tyre strategy. 'It can be different from one race to the next,' says Floury. 'If you look at the season, in Imola we managed to win while not having the fastest car by far, but just by making the right call at the right time. In São Paulo, we managed to win the race because we used the tyres better. In Bahrain, we won because we optimised a few things [and] kept more potential to the end of the race, so it can be different from one race to another, and you have to adapt every time.

'You see that some cars are stronger on some types of tracks. Porsche is strong when the track is flat with high-speed corners, and they can run their car super low, but they were not as strong in São Paulo or Austin.'

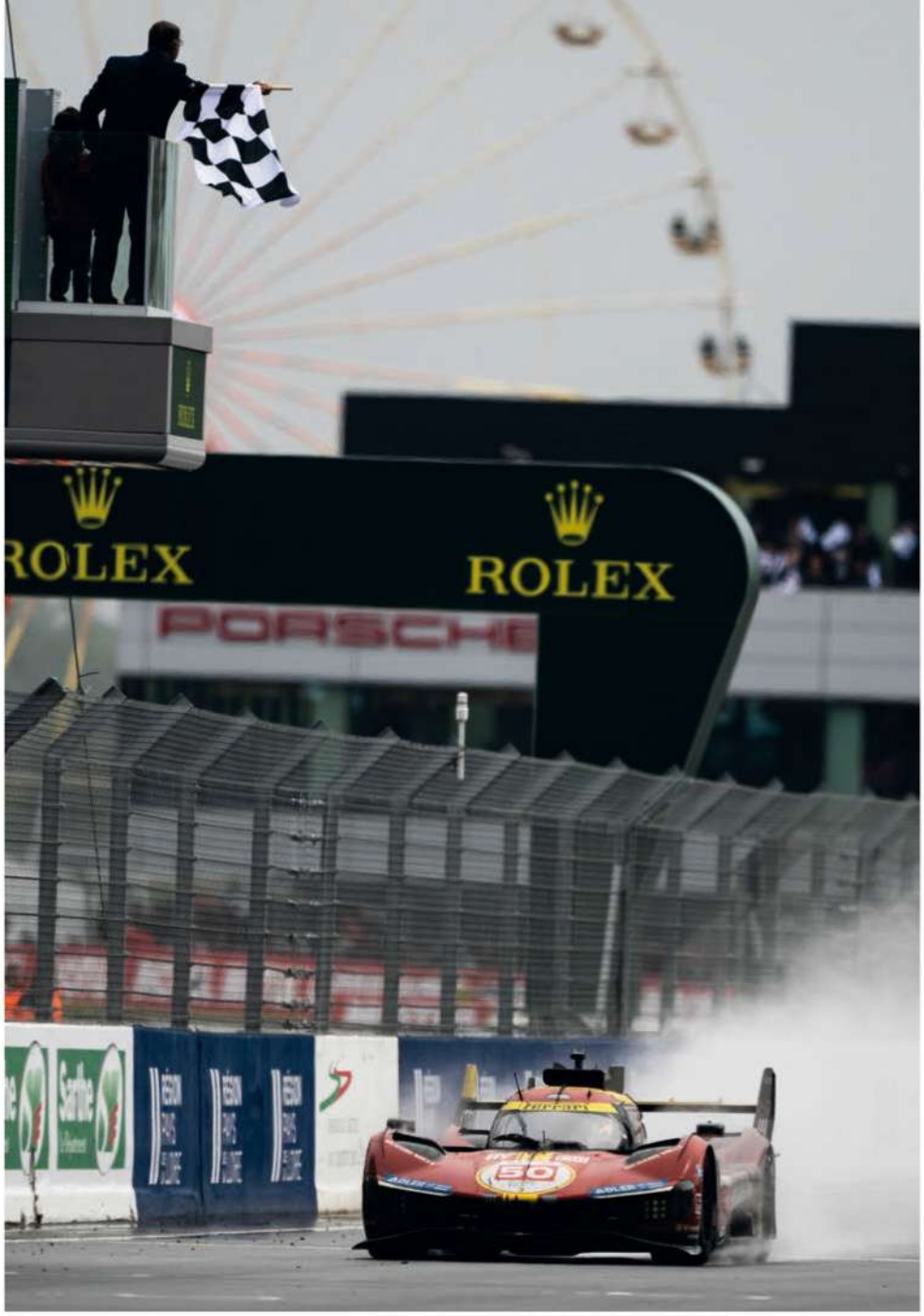
Toyota is one of the few outfits to have tried out a new fuel flow meter from the 2026 Formula 1 supplier, Allengra. The team says it only sampled the new device, and has not used it in race conditions, though Floury notes fuel flow meters are not as critical to performance as they were in the LMP1 days.

Today, the impact of torque sensors is the performance differentiator. Paddock rumour is that Toyota is the closest to the torque curve of anyone on track, with good ride control that can cope with torque spikes over bumps, but the other teams are catching up.

## Ferrari 499P

Ferrari's season started under the threat of the two-stage BoP system that many believed was targeted directly at the 499P. Reason being, the car had a disproportionately high top speed compared to the others when its acceleration up to 250km/h did not indicate such speeds were possible. By introducing a limit of power over 250km/h, the FIA and ACO had the tools they needed at their disposal to combat this phenomenon.

The problem was introducing it to improve the racing and not to unduly hurt Ferrari. For that, the legislators had to have evidence that the 499P did, indeed, possess the top speed advantage the others feared. At the first three races, the FIA and ACO insisted they didn't need to introduce any such restrictions, even when the Ferraris were clocked at nearly 2km/h faster than the third-fastest car from Cadillac at Spa.




**Ferrari took a second win at Le Mans despite the FIA and ACO introducing their two-stage BoP procedure at the last moment**

**Paddock rumour is that Toyota is the closest to the torque curve of anyone on track, with good ride control that can cope with torque spikes over bumps, but the other teams are catching up**

However, the system was then suddenly introduced for Le Mans, where it had the desired impact on closing the gaps, but meant Ferrari still had all it needed to prevail.

Post Le Mans, Ferrari introduced its first update package to the 499P, with all the attention focused on cooling the braking system. 'The update was to optimise the brake cooling distribution between front and rear,' explained Ferrari's head of endurance racecars, Ferdinando Cannizzo. 'We could manage the temperatures [at high braking tracks], but with no margin. It was not a performance improvement: it was to allow a different set up in different races where braking is crucial.

'We wanted to develop the system, but we were not ready. Le Mans is not that tough on braking, but we had an issue in Bahrain last year. We knew we had to manage it at Imola, but knew we had to update the car to be safe.'

Cannizzo denied the upgrade had anything to do with the rear wing, as some suspected. The only aero changes made were part of an update to the front dive planes that helped balance airflow to the brakes.

'We are working on a more comprehensive package, but we need to understand when to introduce it,' said the Italian. 'We are working on the jokers that are available and what we can make as an

**Even with the heavily revised 9X8 Evo, Peugeot still struggled to challenge the Hypercar front-runners. The French manufacturer's best result of the season was third in the Bahrain season finale**

evolution of the car. Really, there is no fixed plan to bring it in 2025, '26 or '27, but we are hoping to finalise the plan.'

## Peugeot 9X8 Evo

Peugeot made the biggest change of all the manufacturers with its introduction of the 9X8 Evo, a winged version of the 9X8, that the French team brought to round two at Imola. The team retained the chassis, engine and gearbox from the original car, but moved weight further to the rear and introduced smaller front tyres and wider rears, bringing it in line with the rest of the grid.

Peugeot hoped this would lead to an improvement in traction under acceleration, one of the previous car's key weaknesses. Some thought it failed in that respect, though technical director, Olivier Jansonnie, said: 'I am not so sure. It was clearly the case last year but, if you look at the last races we did, it is not clear. There are some tracks where we are weak, others where we are good. In Bahrain in sector two, for example, we are not too bad. It is difficult to say, but there is a lot depending on tyre wear, and we are suffering more when the tyres are degrading from a loss of traction.

'We are working on traction control, which is open by the regulation, and it is an area we can improve the car without needing to homologate anything. There are plenty of areas where we can change the car without going for jokers.

'We are not working on a new engine,' Jansonnie adds. 'It is one of the areas where we are one of the best cars, on braking. There are areas around the engine, and engine management, that we can improve.
It is difficult to pinpoint. It is more global what we have to work on. There is not one big thing that will give us one second.'

## Electronic control

As with all the manufacturers, the teams are working on their own coding for the electronic control units. The hardware may be fixed, but the software is open to development, and this is where teams are expecting to make up the most performance. That's easier said than done, however. The engineers needed to write it are either in high demand, or need to be trained.

'We are writing code for the ECU, for the engine, but also for the chassis side, all the hybrid management, the driver aids,' confirms Jansonnie. 'It is difficult to quantify where we are. Everything is so connected in the cars that if you change something in the software; if you improve your engine management for instance, to improve your handling into the corner, because you are managing the engine torque differently on the downshift to help stabilise the car, that has an effect somewhere else.

**'We found some ways around [the compromises], and we try to come back, but anything you do from day one counts. If you want to win at this level, you cannot take compromises'**

*Olivier Jansonnie, technical director at Peugeot*

'Powertrain management overall in a four-wheel-drive car is very open in terms of software and you can tune the car in terms of software. Brake-by-wire you can tune as well.'

There are rumours that Peugeot's programme is the most likely to be stopped abruptly, exacerbated by the upcoming retirement of the project's biggest supporter, Stellantis CEO Carlos Tavares, in early 2026. Peugeot therefore needs better results, especially on home soil at Le Mans, to generate enthusiasm within the company, but that is not easy to come by in Hypercar.

The upshot is, teams cannot afford to carry compromises, and this is exactly what Peugeot has. With as much of the original 9X8 hardware as possible carried over to save money, there is an inherent disadvantage, even in the new car. 'Definitely,' confirms Jansonnie. 'You cannot erase history. It is specific in the regulation. We found some ways around [the compromises], and we try to come back, but anything you do from day one counts. If you want to win at this level, you cannot take compromises.'

That does rather look to be a grim outlook for the programme as a whole, but for now both cars have been entered into the 2025 season. Campaigning for good BoP will likely be key to the French manufacturer's continued presence on the Hypercar grid.

# Mapping the future

**Racecar *talks to Professor Steve Sapsford, author of the Motorsport Technology Roadmap, about what the next 20 years may bring to racing and the wider automotive world***

**By ANDREW COTTON**

Motor racing has traditionally followed a set path when it comes to technology used in the sport, though the increase in manufacturer support, and money, has rather skewed the regulators towards what they require to achieve boardroom sign-off.

In the past, that has included a move to smaller capacity, turbocharged engines, electric racing and then the arrival of diesel in endurance racing. That then gave way to hybrids in endurance and Formula 1 but, more recently, the paths of the OEMs and racing have deviated from each other.

Racing has found itself in the unenviable position of needing to satisfy the needs of the OEMs, while at the same time retaining the essence of competition and entertainment that is the backbone of the sport, as well as staying ahead of technological development.

Cost control has become an intrinsic part of regulation writing, which has rather stifled the innovation. That leaves rule makers with the challenge of balancing manufacturer needs with those of the sport, and innovation.

Series such as Formula E and Extreme E were launched, and manufacturers did jump on board with the former. It continues to

**Arguably, the glory days of hybrids were the mid-2010s, with cars like Toyota's TS050 LMP1 from 2017 proving a dominant force in endurance racing. The period saw rapid development of the technology but at exorbitant cost**

enjoy their patronage. Extreme E, on the other hand, has changed its philosophy and embraced hydrogen fuel cell technology, which has put it out on something of a limb.

Hybrid technology, widely recognised to be an interim step, has now been in place for a decade in both Formula 1 and sportscar racing. It has provided the bridge between sport and the OEMs, leading to improvements in battery technology and motor efficiency, while also helping keep costs under control.

However, the decisions of the FIA World Rally Championship (WRC) and British Touring Car Championship (BTCC) to pivot away from hybrid in favour of sustainable fuels has thrown the cat among the pigeons. Drop-in fuels and hydrogen are starting to emerge as racing fuels of the future, but predicting what the OEMs will continue to invest in when it comes to racing has proved a challenge for the regulatory bodies.

This, then, seemed an opportune moment to revisit the Motorsport Technology Roadmap that has been previously published in 2014 and 2020. Authored by former Ricardo director, Professor Steve Sapsford, on behalf of the Motorsport Industry Association (MIA), most of the trends predicted in the previous two editions have had very little variation, which should be taken as an endorsement of their accuracy and validation of the map itself.

The new roadmap cites cost, sustainability, relationship to road car manufacturers and technology transfer as continued key drivers, and reveals that timelines have remained consistent. However, there are variations and additions, such as the increasing use of sustainable material in tyres, a move to higher voltage electrical systems and the use of hydrogen as a combustion fuel. These all bring their own safety regulations that must be investigated, validated and introduced; this is where a lot of current work is focused.

Sapsford also believes strongly in recyclability so, even if you cannot use a recycled product, you can think about how it can be re-used after you have finished with it.

## Emerging trends

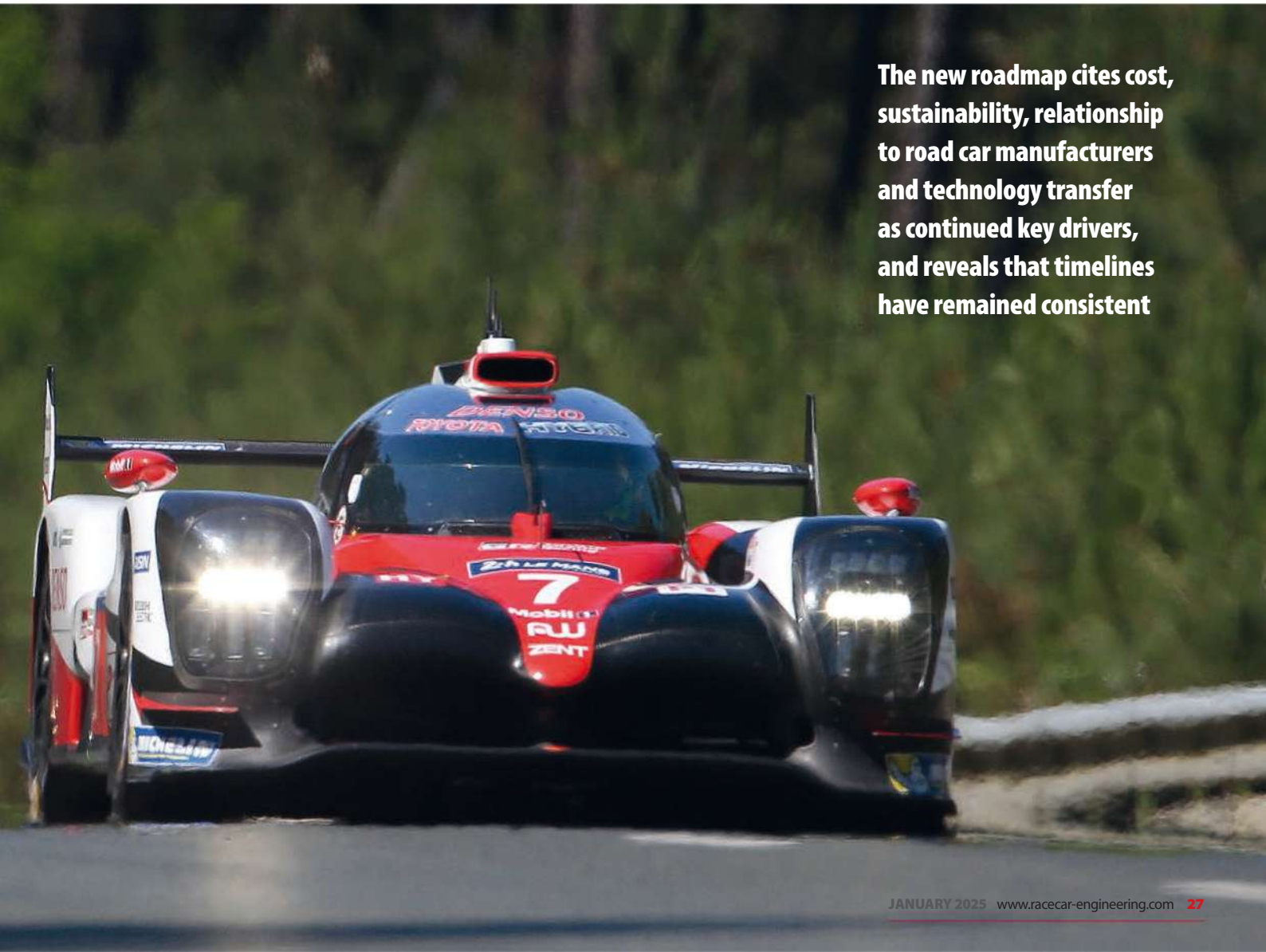
Since the 'Dieselgate' scandal in 2014, the production car world has been turned on its head, with political ambitions driving predominantly European manufacturers relentlessly towards electric cars. The Chinese are similarly committed to electrification, but racing has taken a more modest approach. With the exception of Formula E, which stands on its own as a full electric, FIA-approved world championship, motorsport has yet to fully embrace EVs in other areas, though what is universal is that racing and production automotive are turning away from a reliance on fossil fuels.

F1 will take hybrid to the next level in the new 2026 rule set, with the ICE powering the battery to deliver a high degree of electric power. It will also introduce a new sustainable fuel alongside this new hybrid system, further reducing F1's greenhouse gas emissions.

On the hydrogen front, the ACO and FIA have confirmed their ambition to embrace the technology in the top class of the 24 Hours of Le Mans and FIA World Endurance Championship, while Extreme H has already made the switch from electric to fuel cells.

'I think we are in a period now where the relationship between mainstream automotive and racing is changing quite a lot,' says Sapsford. 'OEMs are becoming increasingly diverse, going more towards electrification, although they might slow down a little bit.'

Up to this point, racing's primary focus for electrification has been hybridisation, but that has not proved especially helpful in the technology transfer from racing to road. Nor has it been widely publicised, with commentators and fans alike largely ignoring




**The new roadmap cites cost, sustainability, relationship to road car manufacturers and technology transfer as continued key drivers, and reveals that timelines have remained consistent**

the electric element of the cars. However, it cannot be forgotten as it is key to opening the door to manufacturer investment.

When F1's new rules arrive, the emphasis might be put back onto hybridisation, but it remains to be seen whether mainstream automotive follows this line of thinking.

Manufacturers and teams will continue to highlight advances in motor efficiency and weight reduction in ever more powerful batteries, but development on both fronts has slowed dramatically from the glory days of LMP1 a decade ago. That came at exorbitant cost, which was unsustainable.

Standardisation of parts within race series, such as a spec transmission, will become more prevalent in future, says Sapsford, as racing continues to seek ways of reducing cost, while also championing sustainability.

## Carbon reduction

One element that runs across both production and racing technologies is the drive to reduce $CO_2$ emissions, yet while production cars are laser focused on electric, racing does not have that same clear path. The move away from hybridisation and towards sustainable fuels in the WRC and BTCC is a perfect example. Sapsford does not believe racing will fully embrace electric technology in the next 20 years, particularly as new fuels reach maturity.

Despite two series dropping hybridisation, it remains a cornerstone of racing regulations, having just been introduced into IndyCar in 2024, and that will encourage developments in cell technology, motor efficiency and advanced boosting systems.

What is interesting to note is racing's move towards higher voltage electrical systems. When the LMP1 regulations were introduced in 2014, it didn't take Porsche and Toyota long to hit on the 800V solution to reduce weight in the powertrain system. Now manufacturers are looking to the new target of 1200V, and the introduction of these systems is expected in the roadmap to be in the early 2030s.

## Hydrogen

Another dramatic shift is the use of hydrogen as a fuel for internal combustion engines. Le Mans is already planning for its top prototype class to be running on hydrogen in 2029. Although it investigated fuel cell technology and wrote its original regulations around this system, Covid delayed their introduction and, when they were re-visited, hydrogen as a fuel had become a hot topic.

New regulations are almost ready to be released and will include hydrogen as a combustible fuel. 'People have talked about fuel cells, but I think it's really important to flag hydrogen ICE, which is a major opportunity,' says Sapsford. 'These engines will have a whole new development story because that's kind of a new area. Early hydrogen engines have been port-injected but they'll likely move over to direct injection. Either way, because they can run very lean, they need a lot of air. The boosting systems are going to become quite clever, over and above the existing advanced system, with all-new areas of development to play with.

'Fuel cells, on the other hand, have also moved on. We already have Extreme H, and I think we will see increased levels of application of hydrogen fuel cells. They will try to get them to run at higher temperatures because then they become more efficient. The biggest problem will come with energy storage management and infrastructure, as well as storage on board, because it doesn't matter if you are using it in a hydrogen ICE or a fuel cell, you still have to store the hydrogen on board.'

Right now, that means housing the fuel in a carbon tank, and tests are ongoing to find a suitably strong vessel that will withstand a high *g* impact, as well as small stone impact. Ballistic tests have been carried out and hydrogen tanks are now set to be regulated for racing application. The roadmap includes development of type 3 and 4 storage tanks to

Formula 1's hybrid era began in 2014 and the premier open-wheel series looks set to take it to another level when the new rule set is introduced in 2026

**[Hybridisation] remains a cornerstone of racing regulations, having just been introduced into IndyCar in 2024, and that will encourage developments in cell technology, motor efficiency and advanced boosting systems**

2035, and type 5, along with alternative storage mechanisms, after that.

The popularity of drop-in fuels will be most keenly felt in historic racing. Using cars beyond their natural lives is an important, and emotive, part of the sport, and making the cars run more sustainably will be a major focus.

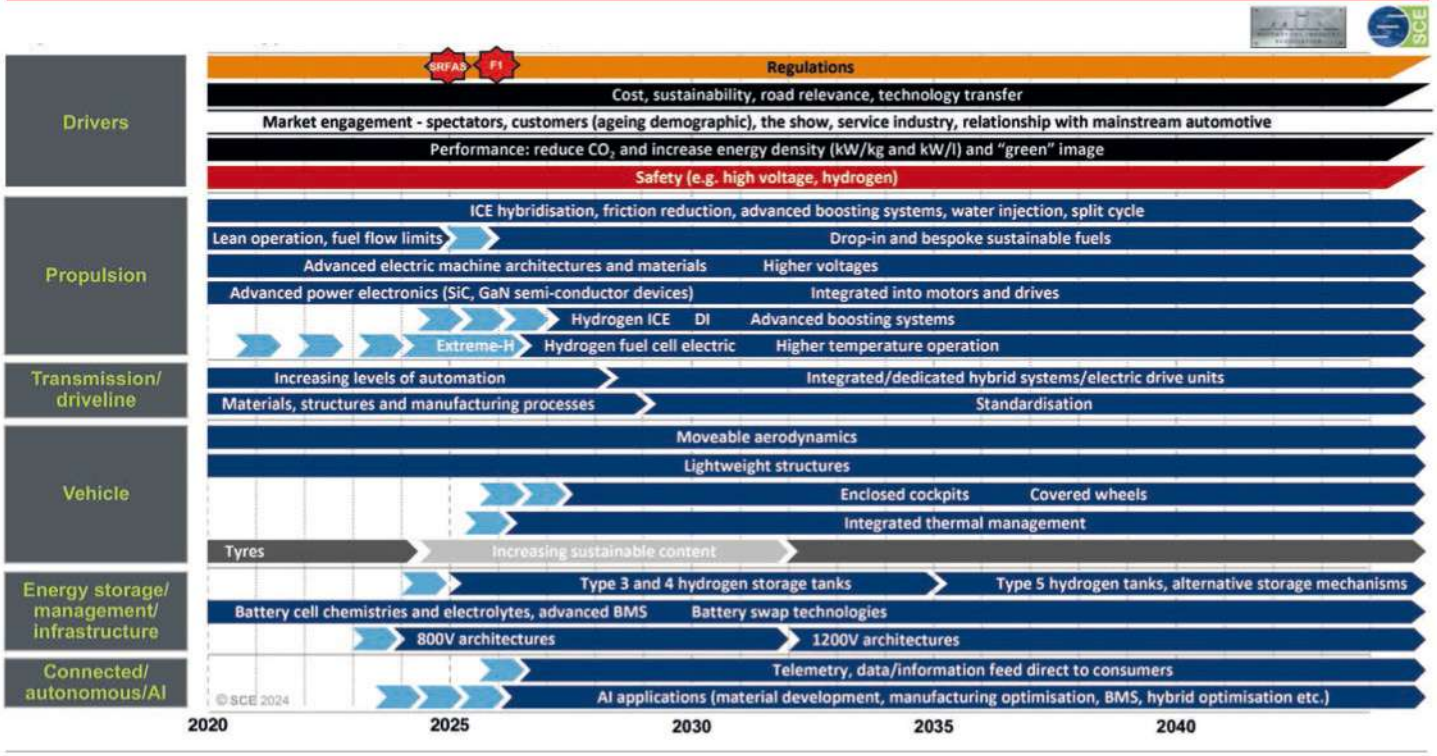
## Synthetic fuels

Already events such as the Goodwood Revival in the UK have run on sustainable fuel, and that trend is set to continue. Developing bio or synthetic fuels that don't cause damage to existing engines would maintain the classic cars, and have a strong influence on carbon reduction, but the fuels need to be produced in volume before they will have a valid production car application. This has always been the limiting factor, even for motorsport use, and the roadmap predicts this trend will continue beyond 2040. Governments, particularly those in Europe, are currently working under pressure from manufacturers to move the date of the ban on the sale of ICE powertrains because of these developments.

The FIA is planning to introduce a new system for measuring the carbon impact of fuel used in racing. Called the Sustainable Racing Fuel Assurance Scheme (SRFAS), it will look at topics such as carbon capture and production cycle, as well as the fuel that goes into the cars. The validation will be certificated, and will need to be open, transparent and accurate.

The scheme has just been announced for F1 through Zemo Partnership, which has developed the Supply Chain Assurance Scheme to independently verify the chain of custody for advanced sustainable components (ASC) to ensure compliance with FIA standards. These areas include feedstock sustainability, sustainable material

## High-level technology roadmap for motorsport 2024




**The Motorsport Technology Roadmap, devised by former Ricardo director, Professor Steve Sapsford, focuses on chasing integrated performance effiently with cost-effective $CO_2$ reduction**

traceability across the ASC supply chain, prohibiting co-processing of sustainable and non-sustainable material and life cycle greenhouse gas emission disclosure. This has already been confirmed for F1 in 2026 and will provide independent assurance of the deployment of sustainable low-carbon fuel in other series.

## Integrated design and AI

Cars across the board will also be designed with greater technological efficiency. Integrating core components such as batteries into the structure of the car will become more refined, while cooling will continue to be a major focus.

Using heat-generating parts such as the exhaust and engine to warm other parts of the powertrain will become more routine, while intelligent use of cooling systems is expected to lead to lighter, stronger cars.

'Building these requirements around the car is very different, and nowhere near as simple as it used to be,' says Sapsford. 'Being clever with your thermal management system, making things operate at higher temperatures and sharing cooling circuits, or exchanging heat between them, is all going to become more important.

'I think probably the flavour of the month is artificial intelligence [AI], and how that can be applied to our area, or in a particular interest,' he continues. 'There are AI applications that are designing new materials, optimising manufacturing techniques and reducing waste; really clever hybrid optimisation systems running AI to improve energy harvesting deployments.'

**'Being clever with your thermal management system, making things operate at higher temperatures and sharing cooling circuits, or exchanging heat between them, is all going to become more important'**

*Professor Steve Sapsford, author of Motorsport Technology Roadmap*

The controlled environment of motor racing is a great place for deploying this technology and teams are already using it, although in different ways: some to help with efficiency in transport, others to run multiple set-up options. 'I don't think that we can even comprehend at the moment, or imagine, the applications that are going to come,' says Sapsford. 'That probably needs a roadmap of its own.'

## Global outlook

Having a roadmap is one thing, but applying it is another thing altogether. European racing is a focus for this roadmap and, in places, the US is currently on a similar path, but what will happen in other countries and continents, such as South America, Africa and China?

Sapsford says these areas will take the parts of the roadmap that are applicable to their needs, and that it's important to do something, rather than nothing.

'If the most efficient thing you can do is an EV for energy use, you're now going to put that in the middle of Africa. But is that the most effective way of reducing carbon emissions there? It could be anywhere, and it could be any technology, but if you don't have the grid, or the electricity is particularly dirty, or you can't run it sustainably, then it doesn't matter how efficient it is: it's not effective in reducing carbon emissions in that territory. A sustainable fuel might then be more effective. It won't necessarily be as efficient, but it will be more effective. Either way, we are going to need a portfolio of complementary solutions and we need to balance efficiency with efficacy.'

One other aspect of development is the increase in telemetry and data sharing with the fans. Spectators around the world are increasingly following racing online, and have for many years watched on more than one screen, with access to live timing and strategy analysis being part and parcel of the viewing experience. With the advent of *Drive to Survive*, the behind-the-scenes docuseries of F1, produced in collaboration with Netflix, the average age of the audience appears to be dropping, and with it has come new ways of telling stories from the paddock. Motorsport is expected to release even more data in the future to engage better with this younger, data-driven audience.

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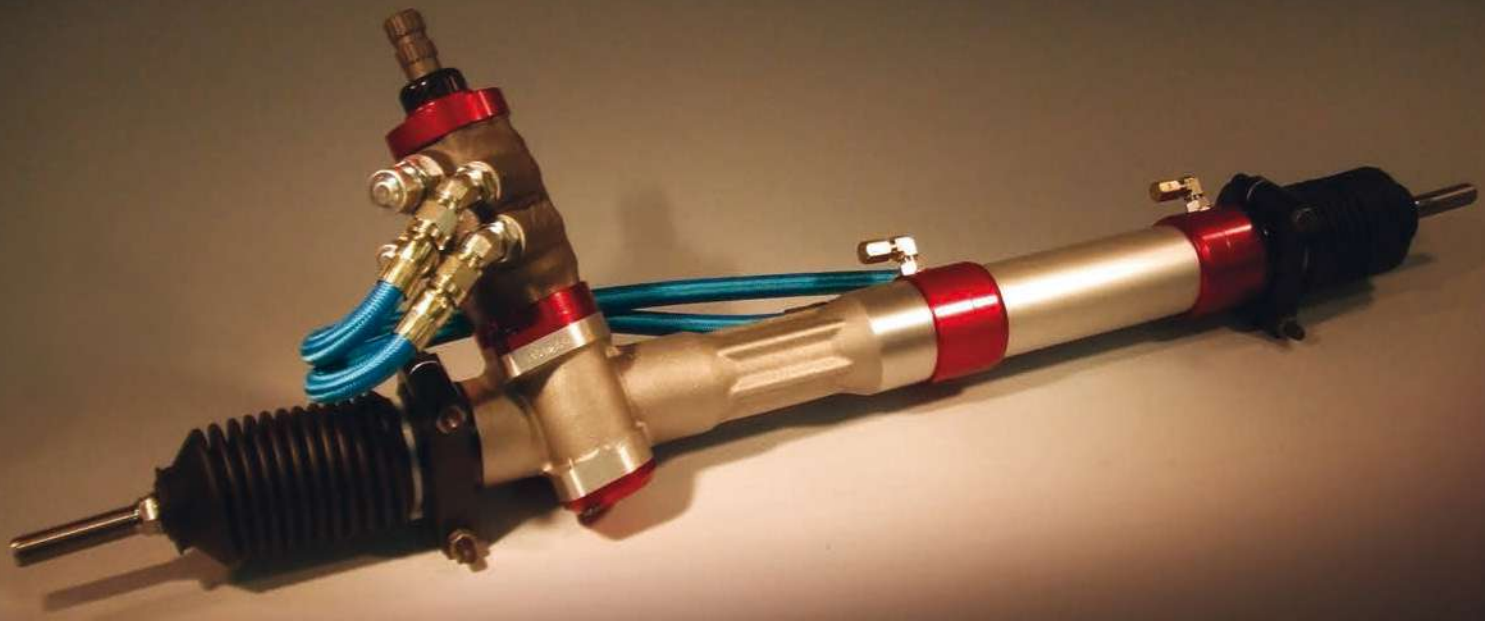

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# Constant 500

*The chassis may be staying the same, but there are changes afoot in Japan's premier sportscar category. Not to electric, though*

By JAMIE KLEIN

Super GT is at a crossroads when it comes to the future of its technical regulations. Like many series worldwide, the Japanese sportscar championship is having to grapple with changing trends in the automotive industry, while taking care to keep its paying audience satisfied as it plots a direction for the remainder of the current decade.

Those that follow the series, both from within Japan and from afar, will tell you that its uniqueness is core to its appeal, and the current breed of GT500 class cars is a major part of that.

The three current GT500 machines, the Toyota GR Supra, Nissan Z and the new-for-2024 Honda Civic Type R-GT, may all look very different, but they are all based on the same chassis, manufactured by Carbon Toray Magic. This was introduced in 2014 as part of a collaboration with the German DTM series, as was the current generation of 2.0-litre, turbocharged, four-cylinder engines that are also used in Japan's other top category, Super Formula.

However, the full implementation of what came to be known as Class 1 in Super GT wouldn't happen until 2020, the year after the DTM finally took the plunge – delayed by some serious foot dragging by Mercedes, which resisted the idea of switching to smaller engines on cost grounds, and then finally quit the championship at the end of 2018.

As it happened, Mercedes' exit proved a harbinger of things to come in Germany, with Audi pulling the plug on its involvement in the series after 2020. In the end, the DTM stuck with Class 1 rules for just two seasons before the concept was abandoned in favour of a move to cheaper GT3 cars. That left Super GT flying the flag for the regulations on its own.

Despite its alliance with the DTM crumbling amid the economic turmoil of the Covid-19 pandemic, Super GT has remained fiercely loyal to Class 1, taking over the rights to the rulebook from the former DTM organising body, ITR. The Class 1 nomenclature was officially phased out in 2023, the regulations now being known simply as Super GT GT500.

## Rules cycle

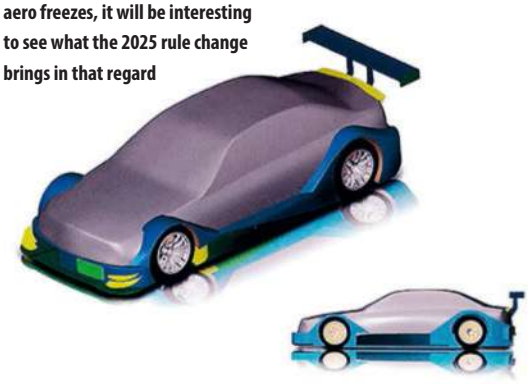
Traditionally, GT500 technical regulations have operated in three-year cycles. The first of these with the current chassis ran from 2014-'16, before changes were made for the 2017-'19 cycle that included a significant reduction in downforce.

However, amid the pandemic, the Class 1 regulations introduced in 2020 were extended by a year, and then at the start of the 2023 season, Super GT organiser, GTA, revealed the current regulations would be extended by another year, making 2024 the fifth (and final) season for the current cycle.

An aerodynamics freeze was imposed in 2021 in the name of cost saving, but was lifted in 2022, allowing Nissan to replace the old GT-R with the Z as its base model of choice. Another aero freeze was then imposed for 2023, and Honda made the decision to phase out its NSX-GT in favour of the Civic Type R-GT for 2024, when new regulations were *supposed* to be brought in.

Assuming no more u-turns, then, next season will mark the start of the first new rules cycle since Class 1's debut in 2020.

**Having gone through two recent aero freezes, it will be interesting to see what the 2025 rule change brings in that regard**



**Three manufacturers currently contest GT500 Class 1. All use the same chassis, built by Carbon Toray Magic, but with their own body styles. Nissan uses its Z…**

**'We are working on the basic premise that hybrids must be introduced. While we haven't reached a definitive conclusion, my personal belief is that we have to consider environmental measures in today's motorsport'**

*Masaaki Bandoh, GTA chairman*

Super GT is hugely popular in Japan, attracting more than 300,000 spectators over the course of a season, and organisers fear turning it electric could drive many of those paying customers away

Images: ??????

…Honda its Civic Type R-GT…

…and Toyota its GR Supra

Most significantly, the existing monocoque design will not be changed. Instead, the 15 racecars in GT500, plus the test cars for each of the three manufacturers, will be given a fresh chassis of the existing specification. This was originally planned to be implemented for the current season, but supply issues contributed to the one-year delay.

Earlier this year, GTA chairman, Masaaki Bandoh, clarified that the next rules cycle, originally planned to run through 2027, will now probably last until the end of the 2028 season. That means the 2014 monocoque design will be 15 years old by the time of its replacement, with the Civic Type R-GT marking the seventh different base model to be built around it (excluding minor variations like the 'Type S' NSX-GT and the '24 Z NISMO).

**Seven different car models have now sat over the Carbon Toray Magic chassis, which has proved itself safe and fit for purpose**

## Safety standard

You might logically assume, therefore, that there would be a desire to create something completely different when the 2029 rules cycle finally commences. However, the current Carbon Toray Magic-manufactured tub has won plaudits for its safety, which has been proven in a series of major incidents in recent seasons. Nissan driver, Mitsunori Takaboshi, walked away virtually unharmed from his high-speed crash along Fuji Speedway's main straight in 2022, while stablemate, Tsugio Matsuda, sustained only minor injuries in a horrifying aerial shunt at Suzuka last year. Honda's Naoki Yamamoto was slightly less fortunate with his crash at Sugo, but has now made a full recovery from the spinal injuries he suffered that day.

Cost is the key factor for Honda's Super GT project leader Masahiro Saiki, when it comes to discussions of the next generation rules: 'If we are going to continue running with prototypes that are based on production cars, then I think the current monocoque is fine,' he says, 'but costs have been gradually rising so, if we can make it cheaper, I think we should.

'As long as we are running cars that are similar in shape to production cars, we have to find a way to make it more affordable, whether that's by making the current monocoque cheaper, or by increasing the number of common components.'

Nissan's Super GT executive director, Shinichi Kiga, concurs with Saiki: 'Nissan's current financial situation is not so good, so we would like to keep the current format with the chassis. Cost control is the most important thing for the future of GT500, unfortunately.'

Toyota appears to be the GT500 manufacturer that is most open to the idea of creating a new chassis, perhaps a reflection of its slightly more luxurious financial position, at least compared to its two major rivals. Masaya Kaji, general manager of the motorsport engineering department at Toyota Gazoo Racing in Japan, notes: 'The current chassis is old, so we could think about changing it, particularly as the DTM is no longer using it. It would be good to use something that was developed in Japan; we don't have to stick to Class 1.'

## Green agenda

As for the GTA, the introduction of a completely new chassis has not really featured on the agenda, which suggests that whatever replaces the current common GT500 monocoque in 2029 is unlikely to be significantly different, even if the supplier is changed.

Bandoh's recent pronouncements about the next generation rules have followed the framework set out in the Super GT Green Project 2030 roadmap that was announced at the end of 2022. As the name suggests, the focus has been on trying to mitigate Super GT's environmental impact, with the goal of reducing the series' carbon footprint by half by the end of the decade, while at the same time maintaining the championship's core DNA.

**'As long as we are running cars that are similar in shape to production cars, we have to find a way to make it more affordable, whether that's by making the current monocoque cheaper, or by increasing the number of common components'**

*Masahiro Saiki, Super GT project leader at Honda*

**The current monocoque design was introduced in 2014 and, with the new rule set planned to run through to the end of the 2028 season, will be 15 years old before a replacement is considered**

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**The Super GT Green Project 2030 has already seen the series introduce carbon-neutral fuel and reduce the number of tyres available**

**'If you ask me, whether having a hybrid system makes things better for the environment… the car becomes heavier, the cost per car increases, there are various issues'**

*Masahiro Saiki*

The first element of this plan was introducing carbon-neutral fuel (CNF), which was achieved in 2023 via an agreement with German firm, Haltermann Carless, under its ETS Racing Fuels brand.

The number of dry tyre sets permitted to be used in a weekend has also been reduced in the name of promoting greater tyre longevity, while the introduction of longer race formats, which have led to longer stints, has also encouraged GT500 manufacturers to focus on fuel mileage at the expense of pure performance with their engine development.

## The next phase

While there are question marks over whether the tyre restrictions have made any real impact, there's no question that fuel mileage has improved considerably since the start of the Class 1 era as all three manufacturers have really pushed the efficiency boundaries.

TOM'S Toyota driver, Ryo Hirakawa, famously ran out of fuel with the finish line in sight at Fuji in 2020, losing the title in the process, having attempted a 42-lap stint. For comparison, in the most recent race at the same track, one of the Nissans was able to pull off a stint of 48 laps without issue.

The next phase of the plan focuses on two areas: what type of fuel to use in the future, and whether or not to adopt a hybrid system. If any major changes are made to the regulations for 2029, it will likely involve one, or both, of these areas, rather than a development of the chassis itself.

Bandoh, in particular, is keen on hybrids, despite the fact the technology is not new.

'We are working on the basic premise that hybrids must be introduced. While we haven't reached a definitive conclusion, my personal belief is we have to consider environmental measures in today's motorsport.

'It's true that not everyone has the same opinion in the steering committee [featuring representatives from Honda, Toyota and Nissan], but I believe it is the job of the promoter to move forward with this.'

## Hybrid systems

While it was largely assumed that Super GT would adopt a spec hybrid system, similar to the way IMSA and the ACO went with their LMDh regulations, earlier this year Bandoh floated the idea of each GT500 manufacturer developing its own custom system. Again, opinions among the 'big three' brands are divided, though it will come as little surprise to hear that Toyota, which pioneered the use of hybrid technology in motorsport in 2007, is in favour.

'We agree with the GTA's aims,' says Toyota's Kaji. 'If it's deemed a hybrid system is needed, then we would be happy to create our own. However, we appreciate there are costs involved, and so a spec hybrid is also a valid option. That would be no problem for us either. But if we do use a spec hybrid, we would like to work together with the other manufacturers to develop the system over time, with the objective of creating ever-better cars.'

In line with Nissan's desire to keep a lid on rising costs, though, Kiga makes it clear he is no fan of having a custom hybrid: 'We are discussing what to do with Toyota and Honda but, if we were to implement hybrids, we would prefer a common hybrid system. Each manufacturer has its own hybrid technology but, if we went down this route, the costs would be huge.

Honda, which actually did incorporate hybrid technology with the NSX-GT when it was launched in 2014, albeit with disastrous results, seems to be the most against the idea.

'For the last 10 years we have taken measures like increasing the thermal efficiency of the engines to improve fuel economy, and introducing CNF, and now it's like, what's next?' says Saiki. 'I think the whole world of motorsport is in a difficult situation now. If you ask me, whether having a hybrid system makes things better for the environment… the car becomes heavier, the cost per car increases, there are various issues.'

## Fuelling up

The other subject up for discussion is whether e-fuels, or synthetic fuels, made from captured hydrogen and $CO_2$, could replace the current ETS-supplied CNF, a so-called second-generation biofuel derived from cellulose. The GTA has also expressed a desire to find an e-fuel supplier within Japan, rather than importing tens of thousands of litres of fuel a year from Europe, although the costs are likely to prove prohibitive in the near term.

Electric propulsion is clearly off the table for GT500. Bandoh has repeatedly stressed the importance of holding 'races with sound' for the benefit of the trackside spectators, of which the championship attracted more than 300,000 last year across its eight rounds (not including those that turned up for pre-season testing and other in-season tests).

And therein lies the rub when it comes to deciding the future of the series. What might be best for the environment may not be conducive to putting on a good show that will keep spectators coming and, ultimately, pay the bills. A good example of this is the aggregate qualifying format that was introduced in 2024, along with a requirement to use the same set of tyres in Q1, Q2 and the opening stint of the race.

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**If hybrids do become a part of Super GT's future, Nissan has stated it would prefer it to be a spec system to keep costs under control, and is in discussions with Toyota and Honda**

It didn't prove a popular move with fans or competitors, and was partially rolled back for the second half of the season.

Although Toyota might be willing to go further than others in terms of measures like hybrid systems and alternative fuels, Kaji stresses that the Aichi manufacturer is 'neutral' and will ultimately go along with the majority. However, there's clear tension between the GTA's publicly stated goals and Honda and Nissan's desire to keep things as affordable as possible.

## Spectator first

Honda, in particular, wants to prioritise keeping the spectator satisfied, above all else.

'I think it's time to reconsider what the spectators are looking for,' says Saiki. 'Is it really the right thing to use this series as a testbed for development? If so, then what about hydrogen? I think the difficulty of deciding what to do in the future is an issue for all of motorsport.'

The GTA is in an unenviable position. It needs to retain Toyota, Honda and Nissan to keep GT500 viable. The DTM provides a clear warning of what can happen when one of the 'big three' decides it's no longer worth competing. The other two might sustain GT500 for a couple of transitional seasons, but the chances of another manufacturer coming along to fill the breach seem minimal. None of the smaller Japanese marques have the cash, and no overseas manufacturers the inclination, at least while Super GT remains more or less a national series.

One of the central aims of the Class 1 regulations was to encourage some of the DTM manufacturers to field cars in Japan, and for the GT500 manufacturers to return the favour by sending cars to Europe. Beyond the exchanges that took place at Hockenheim and Fuji in 2019, that never materialised, although current BMW GT300 squad, Team Studie, did take a serious look at the feasibility of running a Class 1 M4 in GT500.

In 2023, Bandoh talked about the possibility of trying to collaborate with other overseas championships to create a Class 1 successor positioned above GT3, even paying a visit to new DTM organiser, the ADAC, in Germany for preliminary discussions. Such talk has gone quiet in more recent times, though, perhaps a signal it is no longer deemed viable.

The demise of GTE regulations in both Europe and the United States, as well as the failure of projects like the ACO's vision for 'GT3 Premium' cars in the 24 Hours of Le Mans to get off the ground, is a warning sign that appetite for a 'new Class 1' outside of Japan is limited, despite the positive noises made by the ADAC about a tie-up with Super GT.

As such, the GTA would be best served in prioritising keeping Toyota, Honda, Nissan fully committed to the series with the 2029 regulations. In any case, it seems the fundamentals of the Class 1 philosophy dreamt up 10 years ago are here to stay.

**'I think the difficulty of deciding what to do in the future is an issue for all of motorsport'**

*Masahiro Saki*

**Toyota has extensive form in racing hybrid and says it would be happy to develop a bespoke unit for the series, and is happy to work with the other manufacturers to produce it**

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# Vee tech

*It might use an antiquated engine and quirky suspension, but Formula Vee still offers plenty of opportunities for engineering ingenuity*

**By MIKE BRESLIN**

Jon Elsey

Formula Vee has been a staple of the UK club racing scene since the 1960s. Here Craig Bell's AHS Dominator leads a pack through the bends at Brands Hatch

If you know just a little bit about Formula Vee, you might think it's quite a restrictive, even archaic, category. After all, its regulations stipulate the cars use the air-cooled, 1300cc engine from the original Volkswagen Beetle, along with much of the same car's suspension. Dig a little deeper, though, and you may be pleasantly surprised, because not only is Vee (as it is commonly known) open to a variety of different chassis, it also allows for a surprisingly wide range of technical approaches.

Formula Vee has been around since 1967 in the United Kingdom, while Vees also compete in Ireland, the United States and other countries, each of which have evolved their own set of regulations over the years. In America, for example, they use 1200cc versions of the VW flat-four engine. For the purpose of this feature, though, we'll stick to the UK series, where it's probably fair to say this entry-level, single-seater category has always been in the shadow of Formula Ford 1600.

That said, this has perhaps helped it in a way, for while FF1600 has gone through its big budget phases and has waxed and waned as a result, Vee has remained a stalwart of the club scene, offering stable rules and accessible, low-cost racing. Operating under the auspices of the 750 Motor Club (MC) for many years has doubtless helped with this stability, too.

Over 40 different cars raced at some point or other in the 2024 UK Formula Vee series. Among these were chassis from GAC, AHS and Storm, as well as a selection of other makes, with many of the older examples running in Class B – basically for cars with outboard, single-adjustable, steel dampers.

## Beetle juice

What all these cars have in common, of course, is the air-cooled, flat-four, VW engine that powers them, which can trace its origins back to 1938! Such has been engine development over the years that, where this unit gave a maximum of 44bhp in older Beetles, now it's producing about 95bhp in the best units built for Vee. That may not sound much, but it isn't bad in a car with a minimum weight of 380kg (470kg with driver).

This substantial increase in power over the standard unit comes down to the high level of engine tuning that's allowed, as well as the sheer amount of time over which the units have been developed.

'You've got a basic 1300cc engine with a standard crank and pistons,' says Sam Engineer, who, as well as having the perfect name for contributing to this publication, is also the 750MC driver representative for Formula Vee, in which he competes in a Storm chassis, 'but you can vary the compression ratio, you can machine the cylinder heads as much as you like, you can do work on the valve seats…

'Then you've got the top end where you can port it. All of the top end of the engine is free, except for the size of the valves.

'In contrast, the bottom end of the engine is pretty standard, except for the cam.'

That said, flywheels are significantly lightened, while there is freedom as to whether you use a dry or wet sump. The former gives the obvious benefit of combating oil surge, while using the latter – usually with additional baffles – means a simpler, lighter system.

Not that any of these motors are exactly simple, which is shown in the fact that very few competitors build their own powerplants. This is because it takes knowledge, expertise and the right equipment to build a competitive Vee engine.

## Machine heads

'There's a lot of machining work involved, and it takes a lot of time,' says Craig Bell, who is a front runner in his AHS Dominator. 'You need the gear to do it. Obviously, there are the regulations on valve stem sizes, bore etc and you can't afford to make a mistake with that. That's where experience comes into it.'

Two men with that experience in spades are the acknowledged top UK engine builders in the formula, who also happen to build and supply two of the most successful and popular chassis: Alan Harding of AHS and Phil Foster of GAC.

'We're fairly unrestricted as to what we're allowed to do on the engine,' says Foster. 'Obviously, we have got regulations but, because it's a development formula, we are allowed to do quite a lot to them, which means there's massive scope. We can even do our own cam design.'

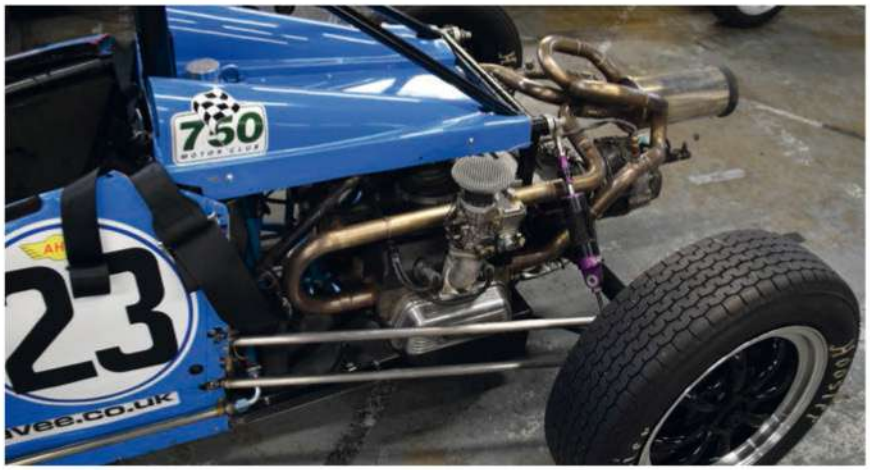
This is one of the key areas of development, though off-the-shelf Scat C45 camshafts remain popular with many competitors. While a good cam is crucial, it is only part of a well-sorted package. 'The cam is incredibly important, but it has to work within the rest of the engine that you're building,' confirms Harding. 'It has to work with the exhaust, the inlet manifold, the carburation, everything. So, you have to know what you want before you build it, not just buy a cam off the shelf and then try and make it fit the car.'

A good example of this is the exhaust design, with many engines requiring long pipes to make the package work most efficiently. There may only be four of them, but the designs can be wonderfully intricate. Harding fabricates the pipes for his engines in-house, and is also well known for his carburettor development. These are free, too, though within set limits.

## Choke hold

'Basically, you're allowed two chokes, and you have to use a 34mm restrictor plate,' explains Engineer. 'You can use a dual choke centre carb with a balance pipe and then use half of the chokes, effectively, per bank, or you can just put a single carb on each bank, but you can only have two chokes in total.'

**The VW Beetle-derived flat four power unit sits low in the chassis, mated to a regular four-speed Beetle gearbox. The best of these engines in Vee produce around 95bhp, this example using a centrally-mounted, twin-choke carburettor**




**Exhaust lengths are carefully calculated, which can result in some intricate systems, as shown on this AHS Dominator, which uses two side-mounted, single-choke carburettors**

Generally, using outboard carbs gives more torque lower down, but the engines don't rev quite as high, we're told, but the positioning of the carbs is just one of the options available. There's also a wide array of carburettor types used, though the Weber 40 IDF, 40mm Dell'Orto DRLA and Solex units are the most popular.

However, just because a carb' might look like a Solex doesn't necessarily mean that's what it is inside. 'We make our own carburettor, and then slide it into somebody else's body,' says Harding. 'That way, we can retain the bits we want and get rid of the stuff that's not needed.'

Harding has also developed the Tillotson for Formula Vee, a carburettor that is better known for its use in karting. 'They're two-stroke carburettors, originally. The benefit in using these is they've got no float chamber, so you don't get surge in a corner,' he says.

As to the attributes needed for a good Vee carburettor, it's pretty much what you'd expect: 'It's all about flow,' says Harding, 'but it's also about atomisation of the fuel against the single inlet on to the cylinder heads.'

**It takes knowledge, expertise and the right equipment to build a competitive Vee engine**

## Cooling challenge

While induction is certainly important, the biggest challenge when it comes to these engines is cooling, for if there's one thing everyone knows about the VW Beetle engine, it's that it is air cooled. So there is no radiator, or other form of heat exchanger.

'You've got two problems,' says Vaughn Jones, a front runner in the championship in his Storm. 'One is keeping the oil cool, so that's with the oil coolers, and the other is keeping the heads cool. We have issues when, if we're sitting waiting for a green flag lap to start, it may take too long and we have to switch the engine off because they just get hotter and hotter. For that reason, I have a

Jon Elsey

**Vaughn Jones' Storm at speed. Note the side-mounted oil coolers on this example. Jones has also installed a sensor system to keep an eye on the temperature of the cylinder heads, which can rise beyond acceptable limits if cars are held up on the grid, for example**

Jon Elsey

**The GAC is based on the Swift SC92 Formula Ford 1600, the only modifications to its spaceframe for use in Formula Vee being those required to accept the Volkswagen torsion bar front axle and engine / gearbox combination**

little digital display I can switch on, which shows the two head temperatures.'

This is such an issue with these engines that Harding developed his AHS cars – first the Challenger, based on an Irish-built Sheane, and then the current Dominator – with cooling as the priority. 'Cooling is far more important than anybody really considers,' he says. 'So, others tend to make a car and then stick the cooling on, whereas we think about cooling the engine and then build the car around it.'

With this in mind, many AHS cars feature 'boxes' – negative pressure areas that draw air over the heads – rather than just ducts to direct airflow over them.

It's not just cooling that needs to be carefully considered. Running these engines involves a certain amount of mechanical care too, especially as some of them are now revved to around 7500rpm, almost twice what Volkswagen designed them to turn.

'They are very temperamental, and you've got to be careful with them,' says Foster. 'If the timing is slightly wrong, you'll get pinking, and you can soon destroy an engine. Generally, we do a full rebuild at the end of the season. As long as you keep on top of them, and make regular oil changes, you can get a full season out of them. Then, most of the time it's just new bearings, though sometimes you've also got to put a set of rings in, maybe pistons and barrels, too.'

## Sourcing stock

Of course, with an engine that has not been built new for the road for many years, finding the right components can be a headache. 'Engine-wise, parts are becoming more of an issue nowadays,' confirms Foster. 'The blocks aren't too bad, and we can still get cases. We have to use standard cranks, so we can get those out of old engines and have them re-ground, that sort of thing. The biggest problem at the moment is sourcing piston barrels.'

The gearbox is the regular four-speed Volkswagen Type 1 unit, the case of which is also used for the Hewland 'boxes made for FF1600 and other formulae. As so many were produced, and they have great longevity, sourcing these is currently not an issue, Foster tells us. He should know, as he supplies most of those used in Vee through his Bears Motorsport business, which is how he became involved in the category in the first place.

**'Cooling is far more important than anybody really considers. So, others tend to make a car and then stick the cooling on, whereas we think about cooling the engine and then build the car around it'**

*Alan Harding, AHS Motorsport*

It is possible to change ratios in a gearbox, to a certain extent, but it's not really worth it. 'There's a very slight choice on ratios, but most of the options take the gearing too high,' notes Foster. 'Unless you've got a really long straight, it's not even worth trying anything else, especially as they're not the quickest thing to change, what with the swing axles in the way.'

## Chassis and aero

Foster's GACs were originally designed and built by Alan Woodward, until Foster bought the rights a few years ago. The car is based on the Swift SC92 FF1600, the only modifications to the CDS spaceframe being those required to accept the VW front axle and engine. It's not the only Vee with Formula Ford DNA; the Storm has Van Diemen bodywork, for example.

Other Formula Vee chassis are generally tubular steel spaceframes, though aluminium or steel monocoques are permitted, and are usually clad with glass fibre bodies designed to aid the cooling of the engine, but also with straight-line speed in mind. This is imperative, given the low power output of the cars, but the aerodynamic treatment goes no further as any downforce-producing devices, or surfaces, are strictly prohibited.

Of course, one person's cooling tweak could be another's aerodynamic device, and some mods do raise eyebrows, but most involved in Vee see this as an integral part of competing in a development formula.

'If people are being creative, that's what it's all about, pushing the technical envelope a little bit,' says Engineer. 'I personally haven't got a problem with some of the aero stuff because it's cheap to do. If you want to make a bit of bodywork, it's not like spending hours on a dyno that's going to cost you lots of money, developing cams and things.'

Bell has probably pushed the aero envelope more than most with his clever interpretation of the regulations on his AHS

**'Most of the trick with a Formula Vee is controlling the rear suspension to keep the camber negative. Every car will have a different way of doing that'**

*Peter Studer, Formula Vee racer and ex-Multimatic engineer*

Dominator (see box out on p43), but ingenuity does not stop with cooling and low drag aero when it comes to Vee, as there's also that quirky suspension to sort out.

## Jack and tuck

Like the engine, the suspension on a Vee is straight out of a Beetle, which means a swing axle at the rear and a double H-beam with torsion leaf stacks within it at the front.

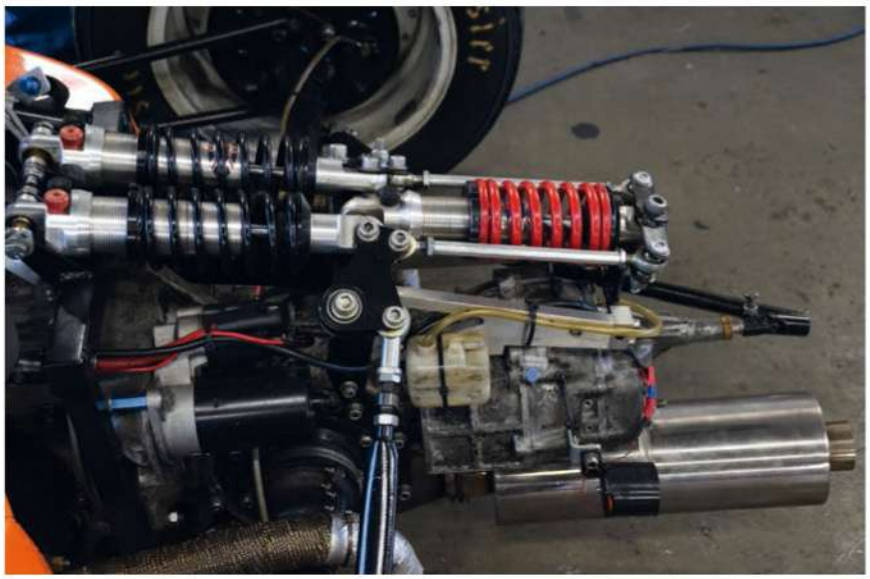
Peter Studer, who runs his own TCR Challenger – a heavily-developed AHS – knows a thing or two about suspension, having worked at Multimatic for 10 years while it was involved in everything from Le Mans to IndyCar to the Red Bull F1 programme. Consequently, he's better placed than many to explain the curious challenge of a Formula Vee's rear suspension: 'The issue with the rear of a Vee is, because it's a Volkswagen Beetle swing axle, it has massive camber gain, which works in both directions. In bump, you get negative camber, but in droop, you get positive camber, and that's the phenomenon called jacking. So called because, potentially, it can literally jack the car over.

'Most of the trick with a Formula Vee is controlling the rear suspension to keep the camber negative. Every car will have a different way of doing that – z-bar, three dampers, one damper, two dampers… Every car has a slightly different variation on a theme.'

Clearly, Formula Vees differ greatly from regular racecars in the approaches taken to suspension tuning.

'If you go into a corner, an anti-roll bar loads up and continues staying loaded, exerting pressure in the opposite direction for the whole corner, which is fine, but on a swing axle that's detrimental,' says Harding. 'It's far better to go into a corner, take the shock out of the corner, the roll out of the corner, into the chassis, but then release it again. And that way the car is quicker out of the corner.'

Many cars adopt what's called a 'zero roll stiffness' approach. Studer explains: 'A lot of cars have got that, and it's very common for a Vee. With this, effectively, all of the roll moment is carried across the front axle. The [rear] wheels stay close to upright and the body twists within them.'



**While the VW Beetle transaxle is mandatory, there are many approaches taken to rear suspension design in Vee. A Storm is shown here with its third damper, which works like a shock, but acts more like an anti-roll bar**

**Peter Studer's car features an underslung shock actuated by pull rods to control heave and a motorcycle steering damper (situated below the carburettor in the picture) for rate of roll**

**Front suspension is the original Volkswagen H-beam with its integral torsion bar stacks and parallel trailing arms. No coil springs are allowed at the front. On many Vees, the front axle is used to control the roll across the entire chassis**

## Say no to downforce

Craig Bell's AHS Dominator certainly stands out from the crowd with its engine cover dorsal fin and shrouded front beam. While these modifications are to do with airflow, Bell is quick to point out that they are in no way downforce-producing surfaces, which are not allowed in Formula Vee.

'The fin on my car is about cooling,' he says. 'If you look at the back of it, it's slotted. You can put your arm through the rear of the car into the engine. And that's the idea: it draws the air out of the back. It's there to get rid of the hot air, so the air coming either side of the fin creates a vacuum at the back of the car, which pulls hot air through.

'It's legal because it doesn't create downforce. That's because it's straight planed, it's not a wing. In the regulations it says as long as its primary function isn't downforce, it's legal. Well, the primary function of this is cooling, but it doesn't create downforce anyway.'

While Bell says the fin certainly helps with engine cooling, he's not sure if it provides any straight-line speed advantage, saying, 'if it does, it's negligible.' However, the aero mods at the front have been made with precisely this in mind.

These are 'ducts' that shroud the beam and, at time of writing, Bell's AHS was the only car on the grid that sported them. 'It's drag reduction,' he says. 'The problem with a round tube is it's horrendous for aero, so that's what the ducts are designed for – to make that round tube into an elongated shape. You have to keep everything straight planed, so the ducts on the front beam are bang on symmetrical, top and bottom. Obviously, if I had made them like an [inverted] aeroplane wing, that would be illegal.'

The VW front beam is enclosed to help cut down aero drag from the round tubes. Because the shrouds are symmetrical top and bottom, they do not produce downforce

Note the wide slot in the rear of the dorsal fin. The vacuum formed by the airflow either side pulls hot air away from the engine. Aero mods include boxed-in carbs

Jon Elsey; Bresmedia

A zero roll car will often, but not always, run three dampers on the rear but, as Harding explains, the third is not really a conventional damper. 'They look like a shock absorber, they work like a shock absorber, but they don't do the same thing. It's more like an anti-roll bar.'

Studer's car is a bit different in having a pull rod-operated monoshock, which controls the heave and is placed beneath the gearbox to keep the weight low in the car. 'Then I've got a set of pushrods with opposed rockers working a motorcycle steering damper that controls the rate of roll, the roll stiffness,' he says. 'So, it doesn't change the amount of roll, it just changes the rate of roll.'

## Independent thinking

Being a transaxle, the gearbox itself also plays its part in a Vee's rear suspension system. 'Another trick thing, which was sort of there from the AHS days, is I've got the transmission mounted in a cradle, which allows you to independently jack the chassis up to raise or lower the rake, without changing the camber,' notes Studer. 'Because on a Formula Vee, you make one change, and it changes everything else. Change the ride height, it changes the camber; change the camber, it changes the ride height. But with this I can independently change camber and ride height.'

At the front, the VW torsion bar suspension is mandatory. All cars must run with a VW beam axle, which is a trailing link design, including the hubs and stub axles (spindles).

**'The beauty of Vee is you have a set of components that every car will be running, but how you join them front to back and control them is totally down to you'**

*Peter Studer*

The quicker Class A cars will use pushrods and sophisticated, inboard dampers from the likes of Öhlins, Quantum and others, along with an anti-roll bar.

All this can lead to pretty stiff racecars, and it's interesting that Formula Vee drivers will often avoid the kerbs: 'I keep off them,' says Bell. 'These cars just bounce over them and you can break them. They can't take kerbs.'

Other components of note include the brakes, which must be the original drums on the rear, though friction material is free, and standard VW Beetle disc brakes on the front. Meanwhile, durable Hoosier treaded control tyres help keep a check on budgets.

All of this adds up to racing on a relatively low budget. Most competitors we spoke to said that spending around £10,000 (approx. US$12,670) is perfectly feasible for a season's racing, though this does depend on how many, if any, engine issues are experienced, and how much testing is done.

Should the worst happen, replacement parts are inexpensive, too. 'A chassis you can buy for around £7000 (approx. $8900),' says Engineer. 'Then the engine, it depends on how much you want doing to it, but probably a similar number again.'

Should that be outside your budget, a competitive, second hand car can be picked up for around £10,000, while lower-spec Class B cars go for about £6000 (approx. $7600).

## Engineering appeal

However much you choose to spend, there's plenty to keep engineering minds occupied.

'There's loads to do,' concurs Engineer. 'You've got the dampers, the pushrods, brake balance, all the front suspension geometry, the rear suspension… Then you've got the fuelling, your cam, the exhaust, and you can put as much [data] logging in as you want.'

So, while at first glance it might seem restrictive racing a car with an archaic, low output power unit and eccentric suspension, the engineering challenge is far greater than in most single-seater categories these days.

'The beauty of Vee is you have a set of components that every car will be running, but how you join them front to back and control them is totally down to you,' says Studer. Though he caveats that enthusiasm with, 'Vees are an acquired taste, and they do take quite a lot of maintenance.'

# Miller time

*From making carburettors to building engines, Harry Miller was at home in the racing environment of California. But together with designer, Leo Goossen, he built an empire that dominated Indianapolis in the 1920s*

By KARL LUDVIGSEN

After his first visit to Indianapolis in 1911, Miller's creative mind whirred with ideas for the future. Not all were a success, but enough would survive the test of reality to cement his reputation

When historian, Robert Dick, delivered his verdict on the first straight-eight racing engine built in 1921 by Los Angeles racing specialist, Harold 'Harry' Arminius Miller, he was succinct: 'The Miller was a mixture of Ballot and Duesenberg with two overhead camshafts, four valves per cylinder and a crankshaft running in three main bearings.'

This was not Wisconsin-born Miller's first encounter with technology from the 'old world'. Having set up workshop in Los Angeles in 1907, two years later he invented a new type of carburettor he named the Master. At is heart was a barrel-type throttle that progressively uncovered a row of fuel jets as it rotated toward a full-open position.

'The Master performed brilliantly,' wrote Griff Borgeson, 'on racecars, police cars, fire engines and other vehicles that were called upon to do their best under full-throttle conditions. At part-throttle its limitations became more marked as competing carburettors became more refined.'

When Miller first visited 'Gasoline Alley' at the Indianapolis track in 1911, he was fascinated, and soon won many adherents, including Duesenberg, to his Master carburettor. Things progressed from there.

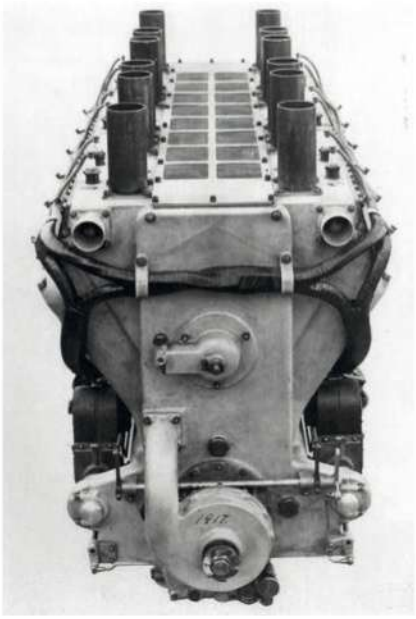
## Fine reputation

John Edwards was chief draftsman for Miller's projects. Needing workshop skills to meet demand, in 1913, the 38-year-old Miller hired the master machinist, Fred Offenhauser. American-born of German parents, Offenhauser was 25 at the time. Granted full authority over the workforce, he gave Miller's plant the reputation of the finest run on America's west coast.

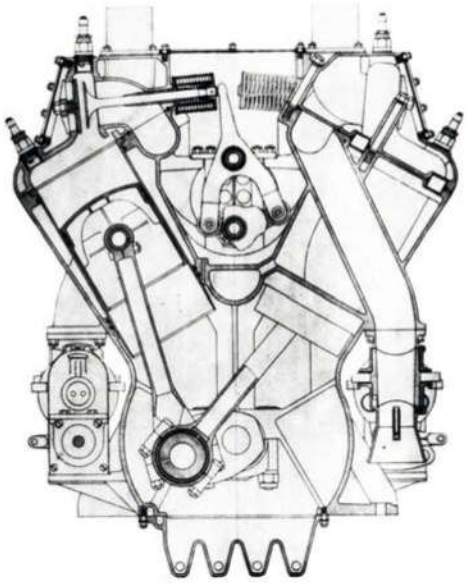
By the mid-1920s, Harry Miller was fitting these beautiful front-drive Miller racecars with his twin-cam straight eights

The company was soon producing lightweight pistons, cast of Miller's 'Alloyanum' material. The Miller shop also began doing odd jobs for the many local auto racing teams. So it was that leading racer and land speed record holder, Bob Burman, turned to Miller when he had a problem. Burman had bought the four-cylinder, 5.7-litre Peugeot that Jules Goux had driven to fourth place in the 1914 Indianapolis 500-mile race. However, for 1915, a displacement limit of 300ci (just over 4.9-litres) was imposed. The star driver needed a capacity reduction for his mount.

Dismantling the ex-Goux Peugeot, Miller and his team had their first look at the innards of Ernest Henry's masterpiece, the winner of the 1913 French Grand Prix, as well as the US Grand Prix and Vanderbilt Cup in early 1915. Their task lay chiefly in creating a new, cast iron cylinder block with its bore reduced to 91.9mm (3.62in) from the former 100mm. They chose to leave the 180mm (7.09in) stroke, and most of the bottom end, alone.



Splendid symmetry marked Miller's proposed V12 aero engine of 1917. He encased its 23.2-litres in aluminium and fitted two carburettors to each flank

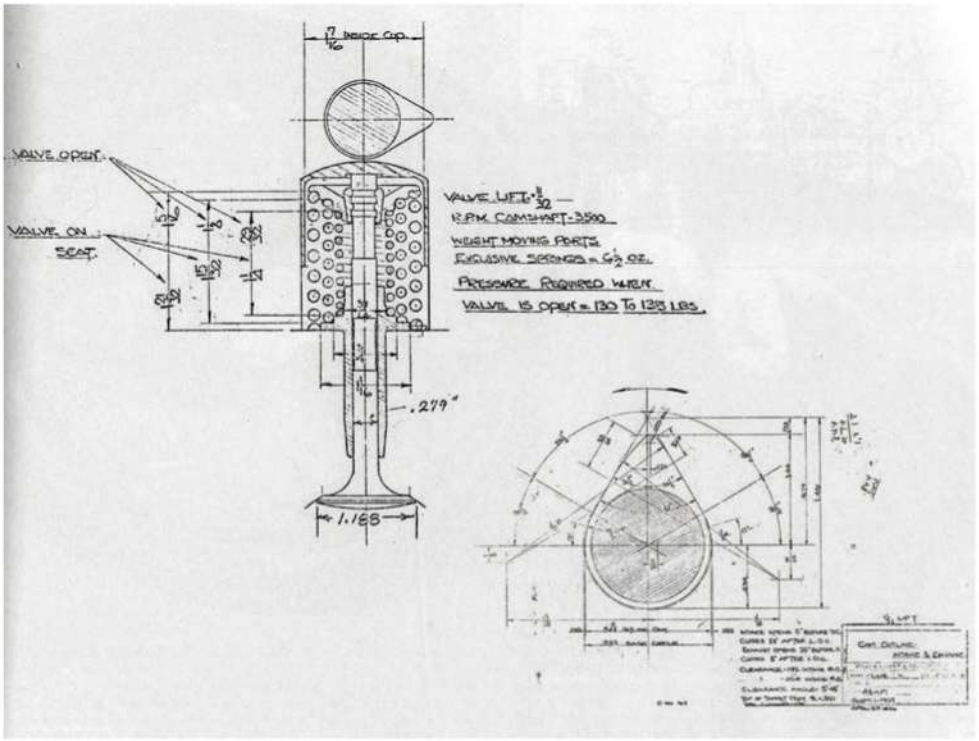


In Miller's V12, combustion chambers bearing a remarkable resemblance to those of the early Duesenbergs were fed and emptied by valves operated by his conception of desmodromic rocker arms

Pictured in later years, Leo Goossen arrived in 1919 to become the right arm that Miller needed to put his ideas down on paper in an orderly and practical manner

**'Miller was without formal education, but a genius and a wonderful guy. His ideas dovetailed perfectly with my Buick experience'**

*Leo William Goossen*




In 1925, Goossen drew this Miller triple-spring valve package. Note the radius on the tappet crown to simulate a roller cam follower

Among changes made by the Miller team were new forged tubular connecting rods and some of the company's much lighter, Alloyanum pistons. Two of Miller's own design of updraft carburettor also replaced the single unit previously fitted. Aluminium access plates for the cylinder block carried the Burman name.

The resulting, smaller capacity racecar brought Burman many top results in 1915, although only a modest placing at the 500, thanks to a failed oil line. In 1916, Burman was duelling with a Duesenberg at Corona, California when a tyre blew. Neither he nor his mechanic survived the resulting crash.

After building a six-cylinder aero engine under contract, Miller set to producing the first power units of his own design.

## The last word

Designed for both aviation and racing use, the engine had four cylinders with four-valve chambers and wet-liner cylinders in a block and crankcase cast in a single Alloyanum structure. A gear-driven overhead camshaft operated the valves via desmodromically controlled, forked rocker arms.

The engine was available with capacity of up to 352ci (5.77-litres) for aeroplane use and 300ci for racing. 'This big four appears to be absolutely the last word in engine design for that era,' wrote Miller expert, Mark Dees, 'but only in automobiles did it make any kind of mark.' It powered a brace of Miller-designed racecars, including the astonishing, enclosed cockpit, Golden Submarine that the legendary Barney Oldfield raced successfully while the rest of the world was at war.

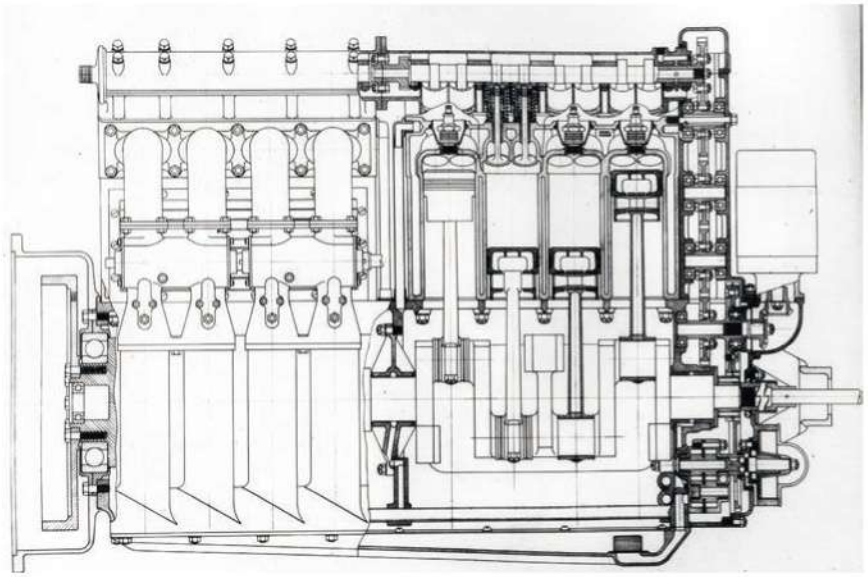
Like the Duesenbergs, Miller essayed a V12 aero engine in wartime. A single central camshaft operated desmodromic rocker arms that opened near-horizontal valves debouching on combustion pockets like those of the Duesenberg 'walking beam' engines. Featuring the huge, light-alloy castings that were a momentary Miller passion, it was not a success.

## Guiding spirit

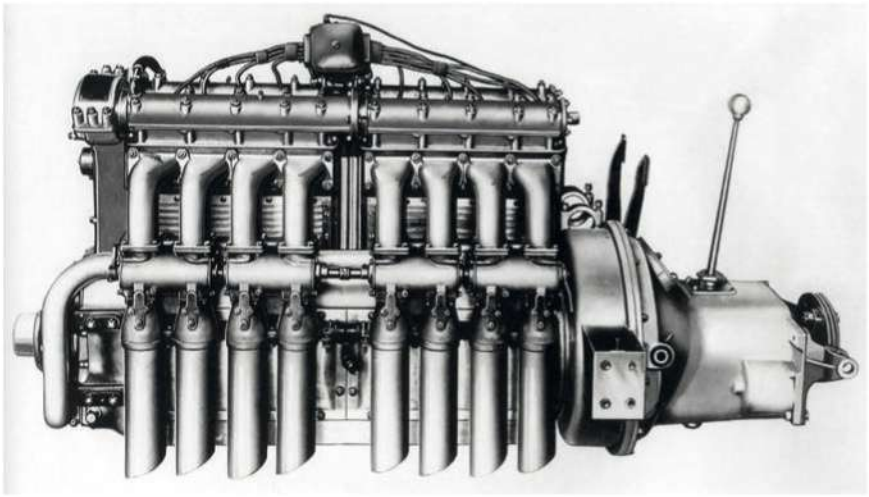
Miller's efforts were bolstered by the arrival in August 1919 of talented engineering designer, Leo William Goossen. At just 19-years old, Goossen had caught the eye of Buick chief engineer, Walter Marr, and been entrusted with tasks far beyond his years. He felt his arrival at the Miller operation was providential, writing that 'Miller was without formal education, but a genius and a wonderful guy. His ideas dovetailed perfectly with my Buick experience.'

To that, Dees added: 'He was exactly the symbiotic partner Miller needed, and for whom, unconsciously, he had been searching.' Goossen soon became the guiding spirit, not only of Miller, but also of its soon-to-be successor, Offenhauser.

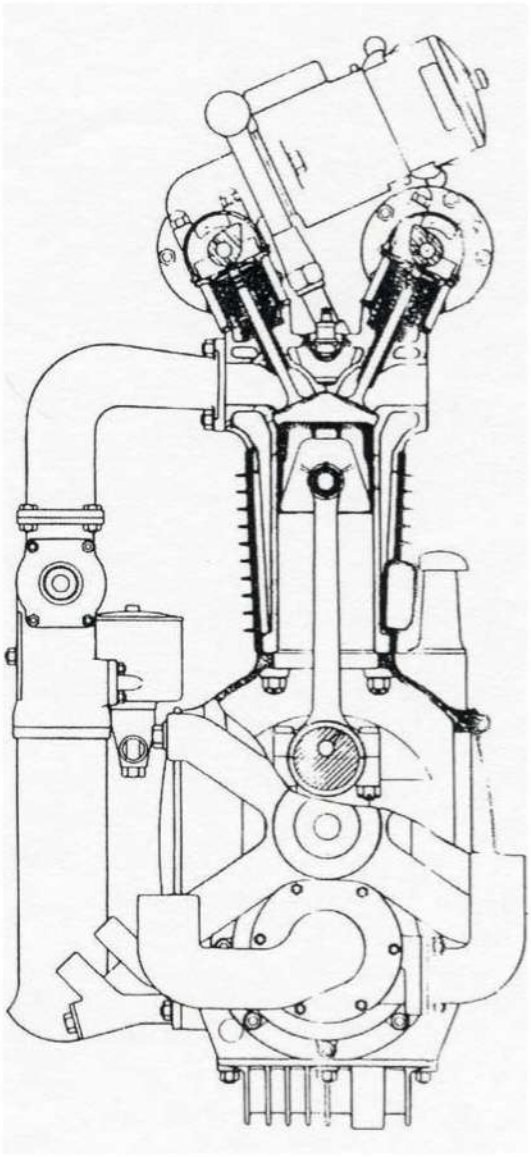
Working with Miller, Goossen had a chance to prove what he could do. Both men learned something in February of 1920 when Ralph DePalma asked Miller's shop chief, Fred Offenhauser, to repair the crankshaft of his



Like Duesenberg, Miller packed his 3.0-litre engine's cylinders closely and carried its crankshaft in two plain bearings and a big ball bearing at the rear. A diaphragm carried the centre main inside a Ballot-style, barrel-shaped crankcase



During the career of the 3.0-litre Miller shown here, and its 2.0-litre successor, the science of tuned-length, individual ram pipes evolved from practical tests on high-speed board tracks



Ballot-type valve angles and quadruple valves were features of the 3.0-litre eights that Miller built and launched in 1921

3.0-litre, straight-eight Ballot, which broke in practice at the fast Beverly Hills Speedway wooden board track. During the engine's dismantling, Offenhauser noted and drew attention to its cup-type tappets. It was their first exposure to such technology and Goossen promptly incorporated similar tappets in a four-cylinder design that was going through the Miller works at the time.

Meanwhile, in Elizabeth, New Jersey, the Duesenberg brothers were finishing work on a twin-eight record car for Tommy Milton. Milton had conceived this use for the redundant 300ci eights and had paid Duesenberg to build the car, pitching in personally to help with its construction.

At the end of February 1920, Milton sent the double Duesey to Florida with Harry Hartz and Jimmy Murphy, asking them to prepare the car for the record attempt while he raced at Beverly Hills to restore his depleted finances. 'When I got back to Key West,' Milton related, 'and picked up the morning paper, it said in screaming headlines that Jimmy Murphy had smashed DePalma's world record of 149.9mph with a speed of 152. I could have killed him when I got there. He understood that and got out.'

Milton could comprehend, but never forgive, the sporting passion of Fred Duesenberg that led him to suggest to Murphy that he test Milton's car at full speed. With the Duesenberg Special already suffering from wear and tear in the sandy environment, Milton had to dismantle and completely re-tune the machine before going on to set a new record of 156.046mph.

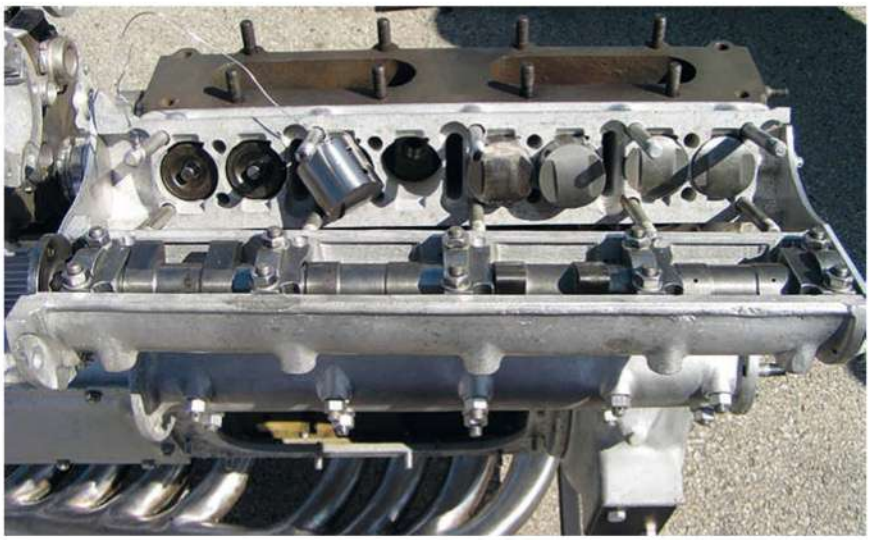
## Special features

Having resigned from the Duesenberg team, the summer of 1920 found Milton racing a car loaned to him by Cliff Durant. It was powered by a 3.0-litre Duesenberg eight that turned out to be one of the lesser units to leave the company's Elizabeth works. Griff Borgeson quoted Milton's reaction: 'At Beverly Hills, I button-holed Fred and said, "Look, this is a lousy engine you sold Durant and either you're going to give us a new one or I'm going to build one that will go." I demanded he give it to us free. He agreed, but his wife, Mickey, talked him out of it on the way back east.'

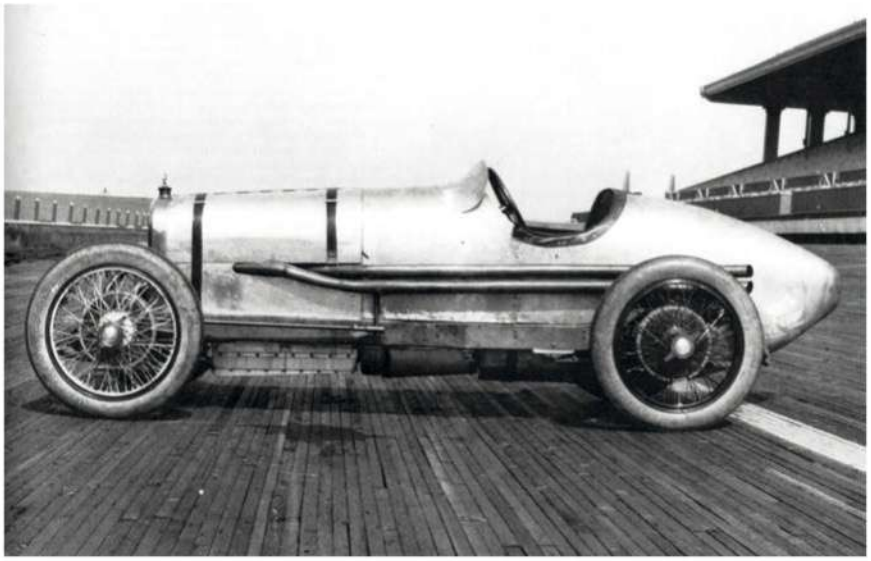
'I was headquartered at Miller's and I discussed new engine possibilities with him. I thought I knew all there was to know about racing engines and my idea wasn't too illogical at that. It incorporated all the best features of all the racing engines about which we knew anything. Among other things, I wanted to copy the Peugeot top end and the 'Duesey' crank with the Peugeot / Ballot rings and passages around the crank cheeks so you didn't have to go against centrifugal force to get the oil to the crank pins.

'Leo Goossen went to work on the design. The engine got built and put in the car and we took it out to the Beverly Hills Speedway for the first big test. It had no speed at all and within 10 miles all the exhaust valves were warped. We modified the cooling system by putting baffles in the block to re-route the circulation, but we still were getting no power.

Thanks to a modern rebuild of a 3.0-litre Miller eight, we have a sense of its internals. Only the first two engines built had these removable cylinder heads, the rest were cast as one with the block



Here we can see the camshaft carrier and radiused tappets, with the latter keyed to their housings to prevent rotation



For paying clients, the Miller shop began building complete cars to go with its engines in the early 1920s. This was Ira Vail's 3.0-litre Miller, fresh from the shop in early 1921. The twin side exhausts were not a permanent feature

**'[Goossen] apparently did a perfect job because my car immediately began running like a spotted-ass ape'**

*Tommy Milton*

'The first man actually to buy a Miller straight-eight 183 was Ira Vail, and when he left that car on the coast he left it for Frank Elliott to drive. I turned a design for roller tappets over to Miller and paid handsomely to have new camshafts made. Goossen had to translate the contours for use with radiused cups. He apparently did a perfect job because my car immediately began running like a spotted-ass ape.'

Milton's reference to 'radiused cups' described a hallmark of Miller / Offenhauser design that departed from European concepts then and later. This feature is thought to have been initiated on a six-cylinder, twin-cam racing engine built by WW 'Cockeyed' Brown in Kansas City, in cooperation with talented mechanics, Cotton Henning and Riley Brett. It first raced powering the Junior Special in 1919 in a Hudson chassis, its cam followers having radiused tops, a concept that endured through the Meyer-Drake era.

## The new eight

In designing the new eight, the Miller team kept the Ballot 60-degree vee between valves while departing from Ernest Henry's long-stroke ideas toward a bore / stroke ratio of 1.49:1 with 68.3 x 101.6mm (2.6875 x 4in).

Only the first two 3.0-litre Miller eights had detachable cylinder heads: all the rest had integral block / head castings. The early eights had four oval inlet and exhaust ports, while later units had eight individual ports for both. This facilitated the application of growing knowledge about the benefits of inlet ram tuning. Output of the 3.0-litre eight was in the 170-180bhp range at 4400rpm.

While the first engines had one updraft carburettor for each four-cylinder module, next came the use of four single carburettors. Milton urged the use of four twin-throat, updraft carburettors, each with a ram tube in its throat, the optimum length of which was determined by experimental trials on a fast board track. Here was a pioneering use of tailored inlet-duct length to create resonance in the tubes that would increase the density of the incoming charge at valve opening.

Although the 1922 finishing list at Indianapolis was top heavy with Duesenbergs, Jimmy Murphy's winning chassis of that make was powered by one of Miller's new twin overhead cam design engines with four valves per cylinder.

First to act on its obvious advantages were the Duesenbergs, who fitted an experimental twin-cam head to one of their existing cars, which had lapped Indianapolis at 98mph in May. In October, now with four valves per cylinder, it proved able to lap at 107mph.

## Hemi heads

Duesenberg would use the same head design for its 2.0-litre eights (60.5 x 86.9mm) for the 1923-'25 racing rules, but Miller had already moved forward with an all-new eight with hemispherical two-valve chambers, five main bearings (Duesenberg kept three) and similar dimensions of 59.6 x 88.9mm. This departure from the gospel according to Ernest Henry was urged by Hall-Scott's Elbert Hall, who felt that the hemispherical chamber aided both induction and combustion. A harbinger of this transition appeared in the Italian Grand Prix at the end of 1921 that gifted a valedictory victory to 3.0-litre Ballots.

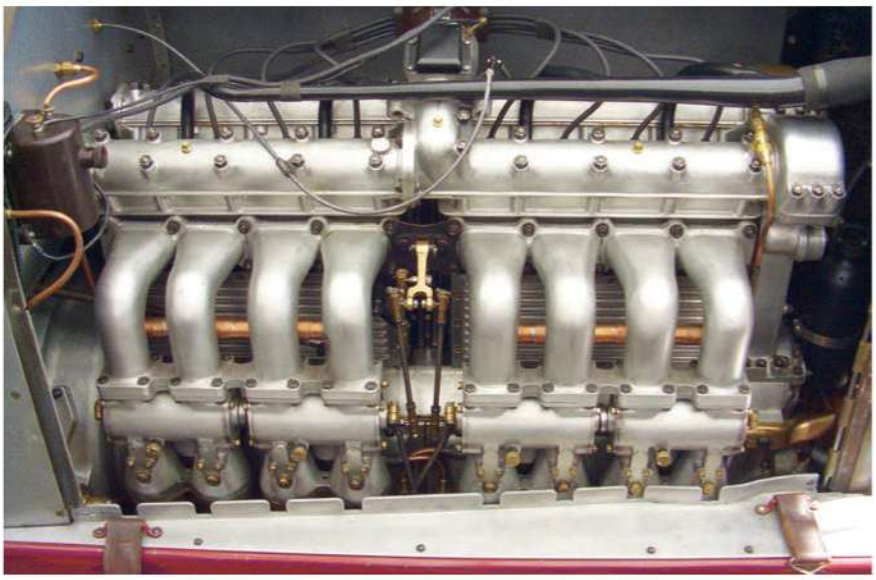
Obliging the French eights by retiring was a three-car team of Type 802 Fiats with straight-eight engines. Their twin overhead camshafts opened two valves per cylinder at the extreme vee angle of 102 degrees, ideal for a pure hemispherical chamber. The work of Giulio Cesare Cappa, the Fiat also departed from existing tropes with its individual, welded steel cylinders and roller bearings for both mains and rods.

Cappa had a chance to reconsider his course of action when he received a visit at Fiat's Special Studies Section from driver, Bartolomeo Costantini, on 12 January 1922 as recorded in *Fiat en Grand Prix* by Sébastian Faurès Fustel de Coulanges. Cappa's good friend was driving a 5/8LC Ballot, offering Cappa and his technicians the opportunity to look over the legendary handiwork of Ernest Henry. Having done so, they concluded they were already on the right track.

## Two-valve future

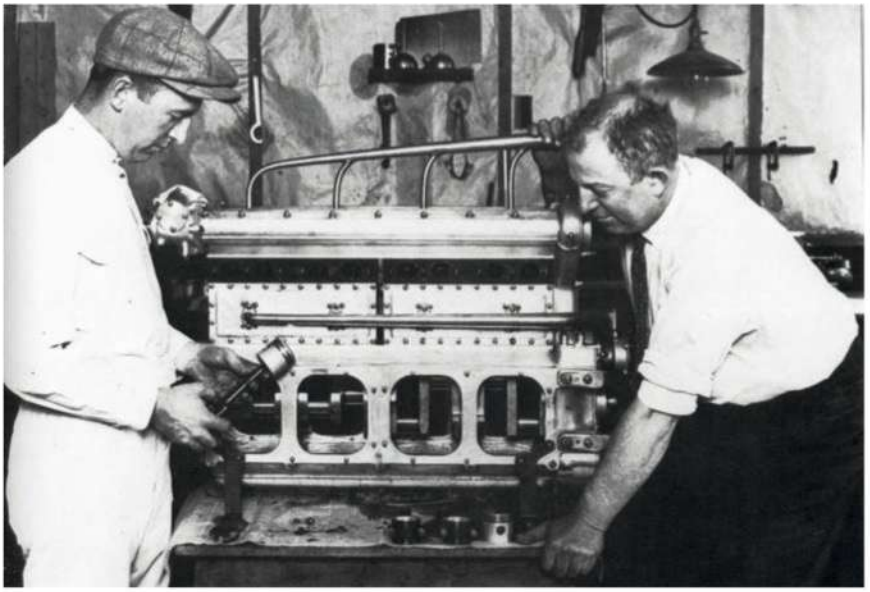
Others agreed that the two-valve chamber was the future, including Miller. His gorgeous, new, 2.0-litre eight was so enthusiastically embraced by the American racing community that it became the first Miller engine to be manufactured in significant numbers. Three were sold to teams to be installed in their existing chassis, the rest powered new Miller racecars. Eleven Miller-motored cars were entered in the 1923 Indianapolis 500 and filled the top four places at the finish.

In 1926, Indianapolis and Europe switched to a 1.5-litre formula, which was to stay in effect for four years in the US, two years longer than in grand prix competition. Duesenberg adopted integral cylinder heads and five-bearing crankshafts in accord with Miller practice. Dimensions of its new engine were 58.1 x 69.8mm, supplying more piston area than the 1.5-litre Miller's 55.6 x 76.3mm.



**Complete with its Delco distributor and quadruple twin-choke carburettors, the 3.0-litre Miller was an imposing sight. It produced 170bhp at 4400rpm with a 7.5:1 compression ratio**

**Loyal to his riding mechanic Ernie Olson, Jimmy Murphy bolted a Miller eight under the bonnet of his Duesenberg to win the 1922 Indianapolis 500-mile race at a record speed of 94.48mph, collecting a purse of $28,075 for his efforts**



**When Miller and Goossen designed their 2.0-litre eight for 1923, they departed from Henry orthodoxy with hemispherical, two-valve chambers. With Miller, Jimmy Murphy muses on the size of piston and connecting rod**

Until supercharging swept the board at Indianapolis from 1925 onward, the gorgeous, 2.0-litre, straight-eight Millers continued to use ram-tuned induction with four twin-throat, updraft carburettors

**Eleven Miller-motored cars were entered in the 1923 Indianapolis race and four filled the first four places at the finish**

Free from 1923 to eliminate the role of the riding mechanic, builders of cars for racing in America sought to reduce frontal area, though few as aggressively as Miller. Only the use of a straight-eight allowed such slim profiles

Fred Offenhauser was well prepared to take over operations at the Miller engine works, having overseen its well-respected machine shop for years

With all the entries now supercharged, some idea of the ultimate pace set by American 1.5-litre cars is supplied by Louis Chiron's entry of a 1927 Delage into the 1929 Indianapolis 500. This champion European car qualified at 107.677mph against a Miller's fastest of 120.599mph. In the race itself, Chiron finished seventh at 87.728mph, while the winning car's speed was 97.585mph.

In 1930, a new Indianapolis formula barred blowers and four-valve cylinder heads, allowed only two carburettors and raised the displacement ceiling to 6.0-litres. Although this so-called 'Junk Formula' was an economic necessity at the time, it effectively ended the magnificent technical development race of the previous decade. Among other retrograde restrictions – unthinkable in today's world – it also required a riding mechanic be carried, a rule that remained in effect until 1937.

Most significant in the running of the 500-mile race's 1930 edition was the second-place finish of a 3.0-litre Miller four, enlarged from a 2.5-litre marine racing engine that was closely related in design to Miller's straight eights of the 1920s.

## Return to four

Unsurprisingly, Goossen had a four-valve combustion chamber design ready to go for a greatly revised version of the four-cylinder engine when the limit to two valves was subsequently lifted in 1931.

Neither then, nor later, did Miller or Goossen dwell on their reasons for reverting to the four-valve head that had served them so well in their early years. Just because it was now permitted was no reason to adopt it, though we can peer over Goossen's shoulder as he draws the new four's characteristics at his board in the Miller works.

The market Miller envisioned was west coast sprint racing on dirt tracks, against Model T and A Ford conversions. For this, they needed about 200ci, some 3.3-litres. Wanting a short stroke engine, Goossen chose the dimensions of 98.4 x 108mm (3.875 x 4.250in). Except for Miller's short-lived V12 aero engine and his V16 for marine racing, this was the largest cylinder bore of any of his engines so far. Goossen readily perceived the value of four valves, especially because they allowed the spark plug to be at the centre of the large combustion chamber. He angled the valves symmetrically at 72 degrees in a pent-roof chamber that was well shaped when married with a piston whose crown had a flat-topped peak. Output was useful at 190bhp.

We mentioned earlier that the Miller shop was a nexus for California's racers, especially those who wanted the inside track on new developments. One such, already fielding cars

**In 1946, Lou Meyer and Dale Drake took over the Offenhauser plant and product from Fred Offenhauser, who had acquired them from Harry Miller in 1934**

A smiling Fred Offenhauser is on the far right in this fantastic image showing the variety of high-performance racing engines being built at Offenhauser in 1937. As well as the fours and eights, inline sixes were also made for customers

on the Legion Ascot Speedway in Los Angeles, was Art Sparks. He paid several visits to Miller during the new engine's gestation, as did marine racer, Dick Loynes, and Bill White, who would be the first to have one of Miller's 16-valve big fours. These men may have influenced the decisions that led to Goossen's reversion to the Ballot / Henry concept that would prevail as long as the Offenhauser brand survived.

By 1932, the four had been redesigned to 3.6-litres (103.2 x 107.9mm). Four of these qualified at Indianapolis and one placed second, behind a front-drive Miller eight. This light, simple, four-cylinder engine developed 250bhp at 5500rpm.

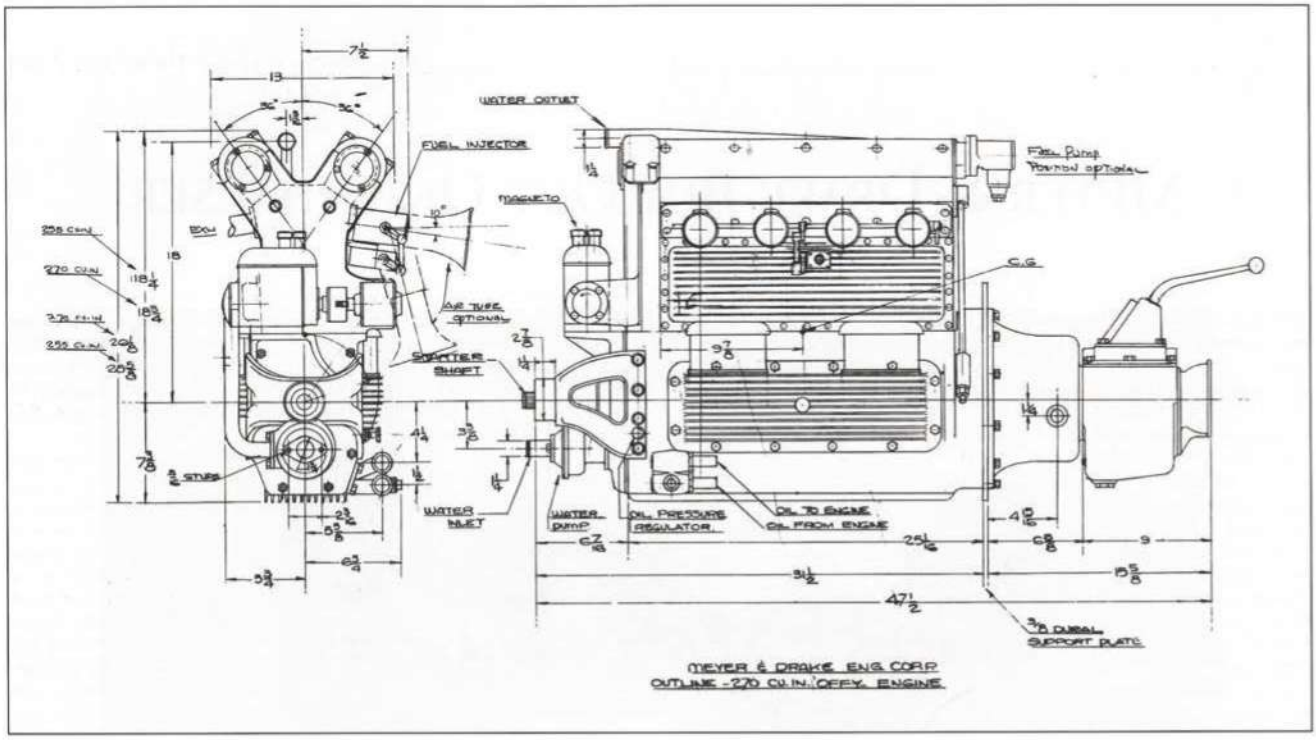
## Scaling up

For 1933, the four's design was scaled up to 4.2-litres, with cylinder centres of 5in (127mm) and dimensions of 107.9 x 114.3mm. This engine, which produced 250bhp at 5000rpm, was the father and mother of all its successors.

Miller's 16-valve fours placed second and third at The Brickyard in 1933, the year in which Harry A. Miller Inc. went bankrupt and Fred Offenhauser picked up the pieces, helped by Leo Goossen and a loyal crew of engineers. Still called Millers, the four-cylinder engines filled the first four places at Indy in 1934, and were dominant through 1937, when the final enlargement reached 4425cc (270ci) with internal proportions of 109.5 x 117.2mm (4.312 x 4.6125in).

In 1946, Lou Meyer and Dale Drake took over the Offenhauser plant and product from Fred Offenhauser, who had acquired them from Harry Miller in 1934. Meyer & Drake continued to call them Offenhausers and, by 1950, 'Offys' powered all but one of Indy's 33 starters, that one being a diesel.

Lou Meyer (left) and Dale Drake (right) with Leo Goossen in 1947. The company was Meyer & Drake by then, but the products were still of Miller extraction




In 1933, Harry A Miller Inc declared bankruptcy. Offenhauser took over and ran the business until 1946, when Lou Meyer and Dale Drake bought him out. As can be seen from this technical drawing of a 270ci four, the company name had changed to Meyer & Drake Engine Corporation, but the products were still referred to as Offenhauser, Offy for short

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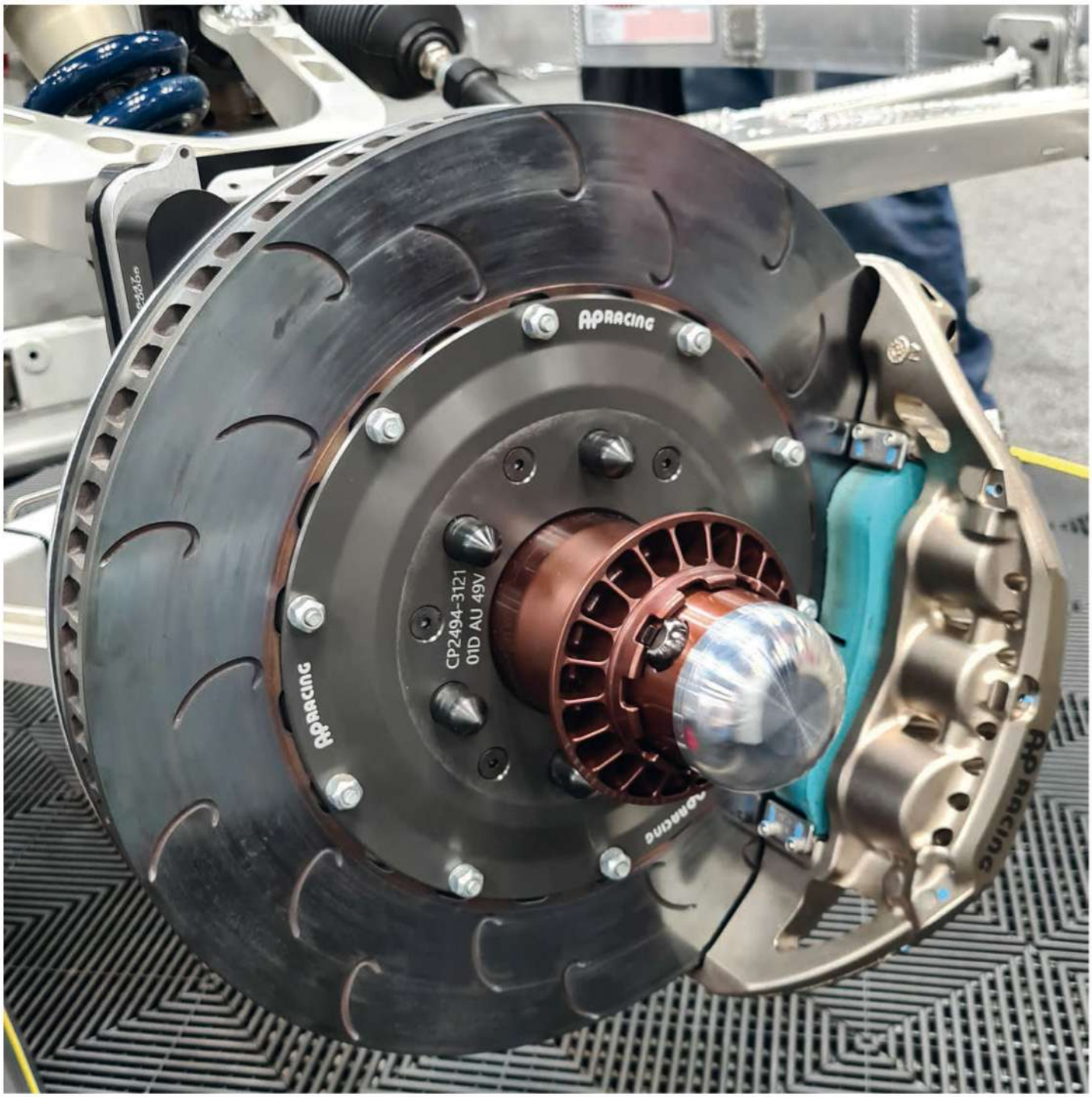



**Where before teams had multiple different brake packages, the NASCAR Next Gen racecar uses the same six-piston front caliper at all tracks. It is only the disc (rotor) that is changed**

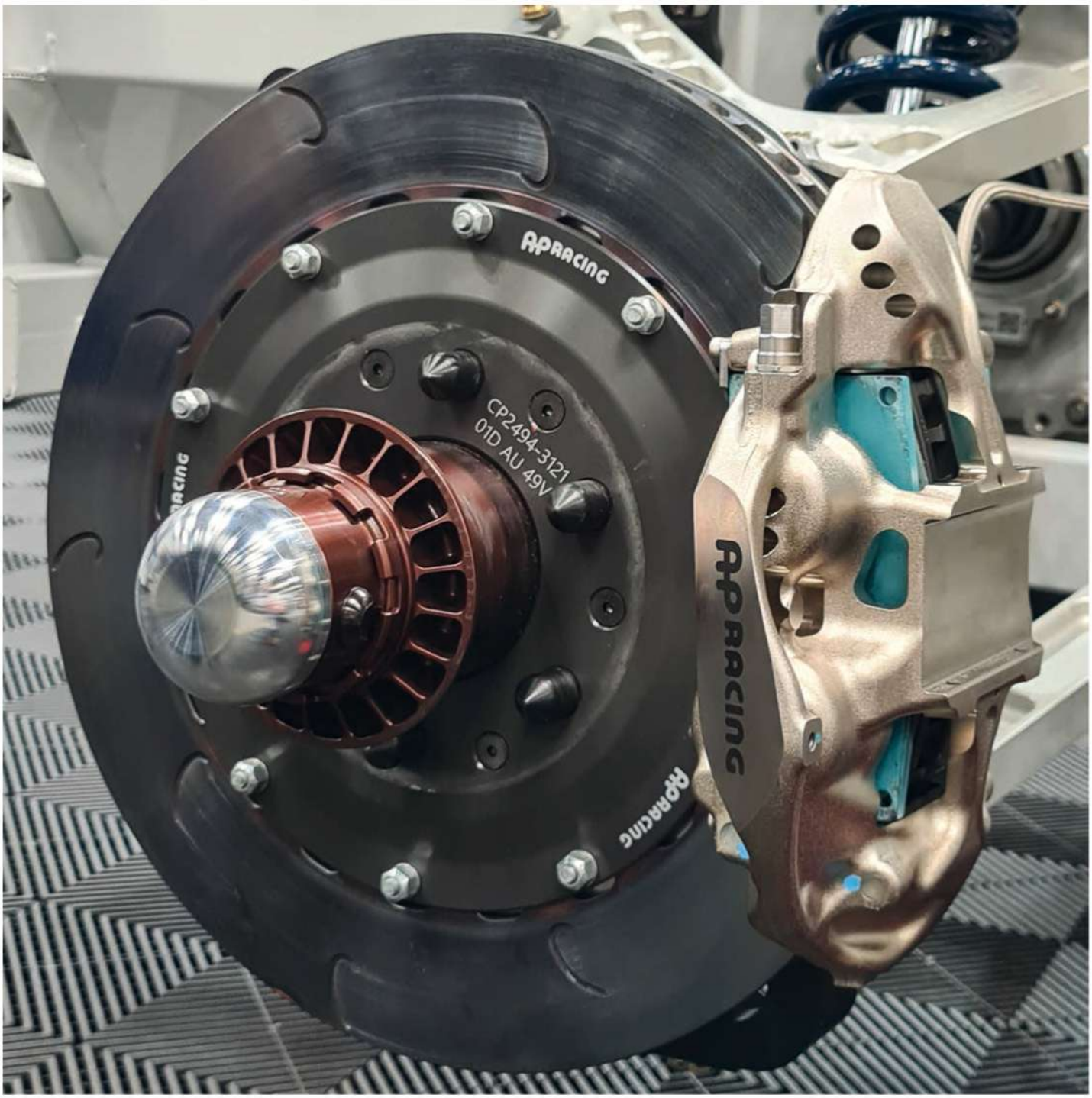
# Brake dance

***NASCAR's decision to move to a single supplier for its Next Gen car's braking system led AP Racing to a novel approach with the design***

**BY ANDREW COTTON**

There was a clear goal for NASCAR's Next Gen car when it was under design: reduce cost, without compromising quality. To achieve that, the sanctioning body moved towards a single supplier in some areas, including the braking system. The target was to reduce the cost of the package by around 50 per cent, compared to the previous Gen 6 system, and a tender process was initiated to find the chosen supplier. UK-based AP Racing exceeded that target relatively comfortably, and won the tender to supply the brakes.

From an engineering perspective, it was no easy task to bring down the cost, while at the same time retaining the performance




**Likewise, at the rear. A single four-piston caliper is the only option available, though teams can choose between a light-duty and heavy-duty disc. Both use AP's innovative direct drive fitment**

level seen on the previous car generation. However, AP Racing was helped in several areas by the regulations, which included an increase in wheel size from 15 to 18in diameter, which offered more space to fit a physically larger, more robust brake package.

The Gen 6 cars were extreme in that they had bespoke brake packages per driver, per car and sometimes per race. Naturally, competition in the area of brake systems was fierce, and expensive, with multiple disc and pad configurations, different caliper designs and perhaps more than 100 bell designs to house the various braking systems. With very low production runs, costs ran out of control, so saving money should have been easy. The hard part was ensuring the drivers and teams were not disappointed by a new system that they all had to use.

There is certainly no shortage of experience at AP Racing. The Coventry-based company has supplied NASCAR since 1987, with 13 title-winning cars using its products, before it won the tender to become sole supplier for the Next Gen era.

## Rules of the game

As with all single-supplier deals, the rules of the game change slightly. Outright performance and development are replaced by lower cost and easier to manage systems, which is just what NASCAR was looking for.

**Saving money should have been easy. The hard part was ensuring the drivers and teams were not disappointed by a new [spec] system**

Braking requirements vary enormously at the different tracks on the Cup Series calendar, so to develop a single package that worked across all of them was no mean feat

AP Racing set about the task by looking first of all at how to bring down the number of options, considering both the racecars and the circuits on which they compete.

The cars run on speedways of varying size, short tracks and road courses, plus there was a specific set up just for Martinsville. Accommodating all these different braking needs was not going to be easy but, against rival brake suppliers, AP Racing believes it hit upon an elegant solution and, ultimately, one that NASCAR chose to adopt.

'What we looked at was how to drive the cost as low as possible, while also making the braking system effective,' says Steve Hood, technical sales manager at AP. 'The system had to be very robust, because NASCAR wanted to make sure the life of the components was acceptable.'

## Combined package

'I was looking at what we had on the old car. They had four distinct packages: road course, superspeedway, intermediate and short tracks. I was looking at all those and thinking, how can we combine and reduce the number of options there? And then I thought, could we do this in one caliper and just offer two different disc options?

'I asked the engineering team to start looking at that, and they said, "Yes, I think we can do this." The bigger challenge, though, is that we had to be able to offer a complete package because, if you're a single supplier and have a brake problem, you're going to have it on 40 cars.'

**[AP Racing] designed and developed an all-new caliper, a single design that would accommodate a larger brake disc in two configurations – thicker for the heavy braking courses and thinner for circuits such as superspeedways**

The company therefore designed and developed an all-new caliper, a single design that would accommodate a larger brake disc in two different configurations – thicker for the heavy braking courses and thinner for circuits such as superspeedways. Cup series teams now use the same six-piston monobloc brake calipers at the front, and the same four-piston design at the rear at every race on the schedule.

Designing adjustability into the caliper so it would accept the different disc solutions was also not straightforward but, since it has achieved that, AP Racing is now rolling out similar designs to other areas of the sport.

## Double duty

'The heavy-duty disc is 380 x 40mm at the front, and with the same caliper we can run the light-duty disc, which is 380 x 36mm. That takes mass out of the disc, and weight, which is quite important because you don't really want a 23lb (10.43kg) disc going 200mph at Daytona,' says Hood. 'We did the same study at the rear, so we have a heavy and light-duty spec there as well, and we managed to do it with only three different mounting bells, which are forged, so we have driven the price down as low as we can.'

Similarly, using the same caliper(s) for the whole season means production costs have been driven down by increased parts volume.

The introduction of the larger 18in wheel not only allowed the use of a bigger brake package, but also better cooling options, so the materials are less stressed now than the smaller brakes in the old 15in wheel. On superspeedways, heavy braking in the Gen 6 car from 200mph down to the pit lane speed limit occasionally led to cracked discs due to thermal shock. The larger disc and caliper arrangement has therefore been beneficial on many levels.

Although component lifespan was an important consideration, the use of steel brake discs means life of the brake is limited anyway, so extending this was another challenge that AP Racing faced.

NASCAR also recently amended the rules so teams can no longer change brakes during a weekend. If they make the wrong choice at a particular circuit, that decision must be carried through the whole meeting. When there were multiple braking packages available, this was an area of concern for teams. Now, having reduced choices not only makes this a more straightforward process,

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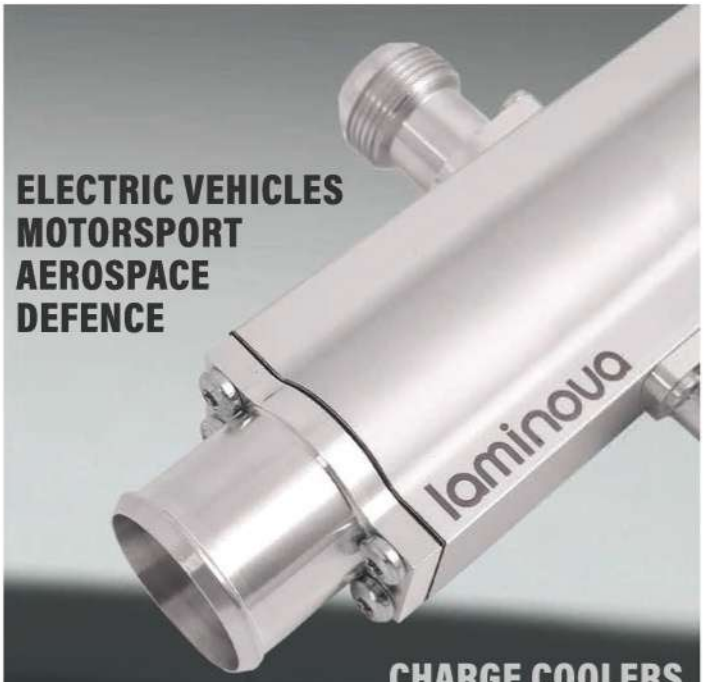


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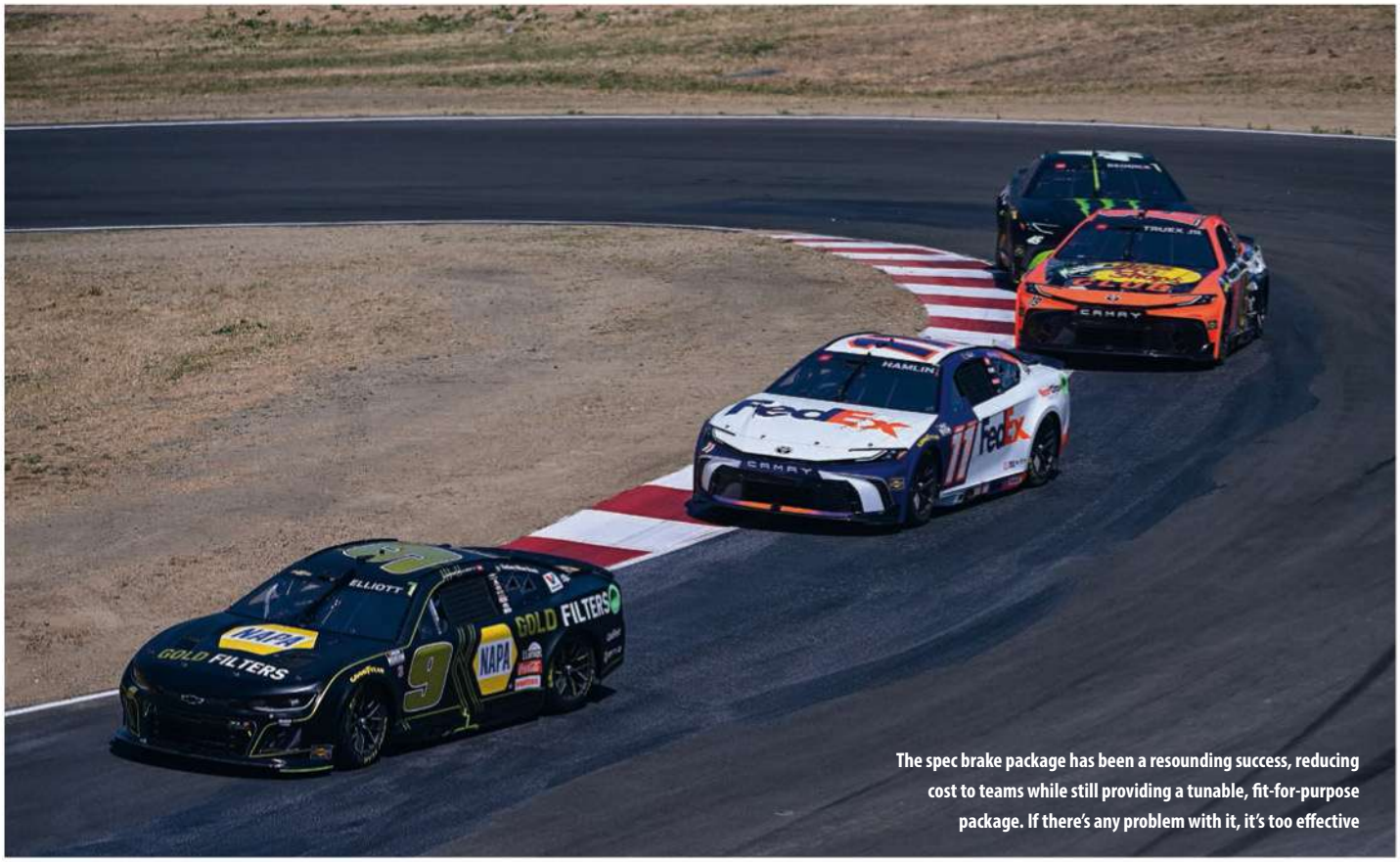


**The spec brake package has been a resounding success, reducing cost to teams while still providing a tunable, fit-for-purpose package. If there's any problem with it, it's too effective**

it means the teams order parts in larger quantities for their sub-assembly shops, which will prepare brake packages for their cars up to two weeks in advance of a race.

For the less well-funded teams, extending the life of a smaller number of brake sets is critical to keeping costs under control. The Martinsville short track, for example, takes the life out of a single set for all teams due to its very heavy workload but, for other tracks, some teams will use the same system for multiple weekends.

'On the intermediate and superspeedway tracks, you can definitely get multiple races out of the same disc,' confirms Hood. 'The thing that has really changed [recently] is that you are not allowed to change [the brakes on the car] during a race weekend. So, whatever disc you turn up with, you practice, qualify and race on.'

## Aerodynamic focus

Brakes also have a role to play in the aerodynamics of the car. Minimising drag while also retaining performance over a stint has been a major focus for teams in all forms of oval racing, with some extreme solutions displayed, particularly in IndyCar. In the Cup Series, though, there is a standard system, and AP Racing had to ensure the new brake package had enough adjustment, while also meeting NASCAR's brief on costs.

'There were a lot of discussions with NASCAR when we did the original design about how much they wanted to have spec, and in what areas they wanted the teams to have a little bit of flexibility,' says Hood. 'One of those was piston retraction. All our calipers have standard retraction, which is just about enough to take the pressure off the pad, but you can still have a little bit of interference between pad and disc.

**'There were a lot of discussions with NASCAR when we did the original design about how much they wanted to have spec, and in what areas they wanted the teams to have a little bit of flexibility. One of those was piston retraction '**

*Steve Hood, technical sales manager at AP Racing*

'One of the things we have been doing for a while now is to look at the seal. There are two ways you can pull back from the disc – one is the seal groove that dictates exactly how far the piston is retracted. You have three angles on a seal groove, including the leading angle. You can put a different angle on the seal groove but then that means you have different calipers. Or you can put an angle on the seal, which is the approach we took.'

Rather than have the seal sit 90 degrees to the disc, there is an eight degree angle to it, which equates to around double the retraction from the disc. The downside of that, of course, is that there is more pedal travel with greater retraction.

Teams are clearly looking for the minimum drag on the disc on the high-speed superspeedways and ovals, so many of them choose the shaped solution for these races as stopping only really happens when the cars are dropping to pit lane speed before a service, and even then, only some of the stops are made under green flags.

'That's one of the things the teams can actually control,' notes Hood.

The opposite end of the scale is Martinsville, where the ability to use the brakes to their maximum throughout the race means different cooling packages are required. AP learned from the 2023 race there that teams were running out of brakes, so worked on different cooling packages for the event in November 2024, which was run successfully. Teams now look likely to use this revised package at other heavy braking circuits, including Watkins Glen.

With such minimal use on some tracks, it helps to have the pads bedded into the brake disc before it's all fitted to the car, and this is a critical part of the whole braking package. The process is handled prior to delivery by Essex Parts Services, a company that beds in the discs ahead of shipping at the teams' request. It's an optional service,

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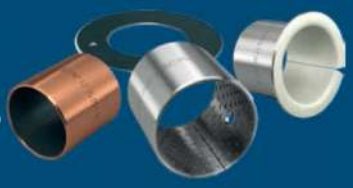

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## Direct drive

**AP Racing introduced a new design of brake disc for the Next Gen car, one that improves the mounting process, while also reducing cost.**

**'Before, most of our brake discs used a bobbin drive,' notes AP's Steve Hood, 'so you'd have flanges on the disc with a bobbin in. The problem with that kind of system is it does give a little bit more weakness in the disc itself. So, over the years, we've developed a direct drive system with tabs on the disc that fit into slots in the back of the bell.**

**'The big benefit of this is it really reduces the stress in the disc. On the old disc they had 12 bobbins whereas now we've got 20 tabs.**

**'It took us a long time to develop that because one of the key things in the direct drive system is the tolerance, the gap between the lug on the disc and the slot in the bell. If you get it too tight then, as soon as the disc starts to heat up, it binds and you lose the float. You've got to have float on this but, if you make it too big, the lugs bounce around in the slots and that starts to beat the bell, because the bell is just aluminium. So getting that gap between the two right took a long time, because it's the most critical thing on it.**

**'It's also more cost effective because it's simpler. You've got a bell, you've got the disc, and then we have a steel band that goes around the inside with bolts. Before, we had somewhere between 12 and 15 different bobbins to give different levels of float, and the teams would have to buy all of those. Then we had instances where the team had put the wrong bobbin in, so the disc would lock up or it would be bouncing around. The new system eliminates that entirely.**

**'So, it's simplified the system, but it's far from a simple solution from a technical perspective; it's just a much better system.'**

but one AP Racing has found to be beneficial to teams, not least because different brake pad suppliers use slightly different properties, so bedding them in correctly is crucial to obtaining maximum performance.

## Tuning options

As well as pad choice, teams can control brake performance with the the type of brake fluid used and the size of the master cylinder to ensure the driver has their own preferred feel to the pedal. This ensures teams have the ability to tune their braking packages, within NASCAR's remit.

'We run a pull-type centre valve master cylinder, but with 10 different bore sizes that the teams can choose from to get their balance right. It goes from a 14.9mm effective bore up to 25.4mm, so there's quite a range there for them to get the feel right,' continues Hood.

'There's also an adjustable slug in the brake pedal, so there are five different ratios available at the pedal. We built as much adjustability – if you want to call it that – as we could into the pedal box, because one of the big hurdles was going from the old car, where everything was designed by the teams and manufactured bespoke for each driver, to a spec package they would all be happy with.'

Three years into the deal, teams have mastered the delivery of balance and feel to their drivers, and AP Racing says it has received no complaints about how the overall brake system works. If anything, they work a little too well.

Whereas before drivers might have needed to baby the brakes a bit, particularly on the heavy-duty cycle road courses, now they are able to lean on them harder, and for longer, through the event. That characteristic has shortened braking distances and reduced overtaking opportunities. Consequently, if there was to be an update, there's a chance the brake performance might actually be reduced slightly to help retain the spectacle for which NASCAR is famous.

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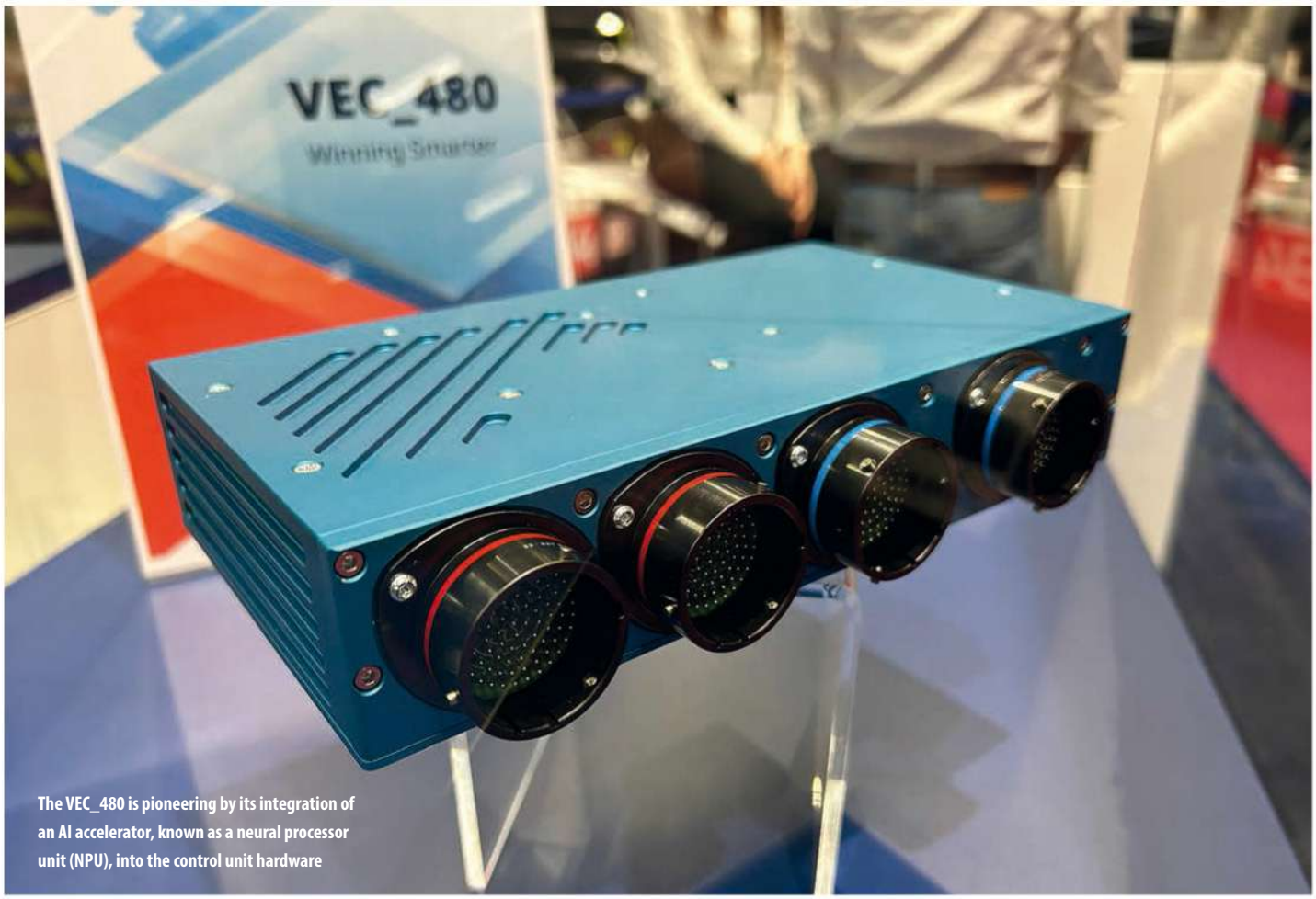


The VEC_480 is pioneering by its integration of an AI accelerator, known as a neural processor unit (NPU), into the control unit hardware

# Smarter control

***The permeation of artificial intelligence into motorsport continues with Marelli's introduction of a control unit with an integrated neural network***

**By DANIEL LLOYD**

The vehicle control unit (VCU) is a device that monitors and harmonises the racecar's key functions, such as engine performance, electronics systems and battery management. VCUs have become more powerful and complex over the years, as they cater to the demands of increasingly advanced machinery. Italian company, Marelli, is aiming to pioneer the next step for this technology in motorsport with its new product, the VEC (vehicle edge controller).

The device features an in-built neural processor unit (NPU) that enables artificial intelligence (AI) tasks to be carried out. The result is a drastic increase in computing power. The NPU of the launch version VEC_480 has a computing capacity of 26 TOPS (tera operations per second). According to Marelli, this is two and a half times more powerful than the family of VCUs it will replace. It also has a 10-times larger inter-processor bandwidth.

The VEC_480 was revealed in November 2024 and swiftly won two accolades. It was named Overall Engineering Innovation of the Year at the Professional MotorSport World Expo in Cologne, and also secured the event's Data and Electronics Solution of the Year prize. Marelli now hopes that manufacturers at the upper levels of motorsport will be convinced to utilise it in series such as Formula E and the FIA World Endurance Championship.

## Inside the edge

With the VEC_480, Marelli has introduced new terminology to the realm of motorsport control unit technology. But what exactly does vehicle edge controller mean?

The term 'edge computing' existed in the world of computing before Marelli brought it to racing. It refers to when data is processed close to its source, usually at the edge of a computer network. In Marelli's case, the use of the word edge is intended to convey how the VEC's AI functions operate fully within the four walls of the hardware, unlike more conventional VCUs with AI compatibility that may cooperate with a neural network, albeit one that is housed externally on a cloud-based computer program.

'We call it 'edge' because 'cloud' means remote, or somewhere else,' suggests Paolo Compagni, vice president of business development at Marelli Motorsport. 'The word edge means nearer the action. Of course, this is more than the edge – it's not near the action, it's inside the action – but it's difficult to convey an acronym for this concept.

Marelli

**Marelli Motorsport CEO, Riccardo De Filippi, poses with the pair of awards bestowed upon the company's new VEC_480 at the PMW Expo**

**'What we decided to do… was adopt the latest generation of micro-controller and couple it with an NPU dedicated for running AI-based algorithms'**

*Riccardo De Filippi, CEO of Marelli Motorsport*

We preferred edge against cloud. The cloud can do some AI systems, you can even get augmented data from it, but the thing [with the VEC_480] is that the NPU is inside. It can work without any connectivity at all. It's autonomous calculation.'

Marelli's range of VCU products currently run on a multi-core processor, but this existing technology isn't powerful enough to exploit the full potential of AI.

'Normally, we have one main processor in charge of all elaboration of dynamic strategies such as torque control, stability control and gearbox management,' says Riccardo De Filippi, CEO of Marelli Motorsport. 'In our case, we had a multi-core processor from the latest generation of micro-controllers. Powerful enough, but standard stuff. What we decided to do, based on our experience from the field, was to adopt the latest generation of micro-controller and couple it with an NPU dedicated for running AI-based algorithms.'

For several years, racecar manufacturers have been using neural networks to transfer results to the control unit for a particular function. Seeing that more of them were exploring the use of neural networks to interpret strands of vehicle data, Marelli started investigating how it could streamline the process by embedding a neural network into the control unit itself.

## The brain's brain

VCUs are often described as the brain of the racecar. In the case of the VEC_480, the NPU is the brain of the VCU, being a type of processor that can handle extraordinary amounts of data.

NPUs came after CPUs (central processing units) and GPUs (graphics processing units). CPUs handle general computing tasks, but are not very good at handling different tasks in parallel. That led to the development of GPUs, which came on stream at the turn of the 21st century and enabled computers to perform a wide range of tasks simultaneously. Best known for rendering graphics in video games, they are also used for training neural networks. However, as neural networks became more advanced, GPUs couldn't always keep up with computing power demands.

Malcolm Griffiths / Formula E

**The VEC comes with or without an ignition / injection driver, making it suitable for hybrid and all-electric applications. It can also be added to an existing layout to increase computing power**

This led to the development of NPUs in the mid-2010s, designed specifically to train neural networks, working on functions that are too intensive for a GPU to handle.

'Neural networks are very powerful and demanding,' says De Filippi. 'The way they are structured, they tend to overwhelm a standard processor. Those units – NPUs and GPUs – are meant for making lots of calculations, so they have plenty of cores running in parallel. They are specially designed to cope well with that kind of algorithm. You might already find [VCU] devices with NPUs on board, but mainly for image processing. The fact we combine them in a single unit means the link between the standard processor and the NPU is optimised for data transfer.'

The Marelli NPU is connected to the control unit in which it is housed, at PCI Express level. A bus then links the control unit's processor and the NPU, minimising latency in the sharing of information.

## Real-time reading

Neural-based algorithms – the instructions given to an AI device – are continually becoming more complex as they learn from prior use cases. The NPU in Marelli's control unit is designed to handle data using these instructions in real time, during a racing scenario. It can be used for data interpretation, real-time video processing, object detection, localisation and positioning, performance analysis, predictive analysis and voice recognition.

**The VEC_480 is also able to learn how a racecar's physical sensors work under different conditions. This enables it to identify when and, more importantly how, a sensor has failed**

'In Formula E, energy consumption is key,' explains De Filippi. 'You could run an algorithm to learn in real time how the driver is making use of the available energy, and how you could optimise, or suggest how to modify, their behaviour. Or adapt the gear change rather than using the KERS system. Or how to recover energy in a more efficient way, by learning and adapting to what is happening in the race. This becomes very versatile in scenarios where you have to learn and adapt strategies in real time.'

The VEC_480 is also able to learn how a racecar's physical sensors work under different conditions. This enables it to identify when and, more importantly how, a sensor has failed, allowing the user to deactivate the faulty device and switch to virtual sensing where the VEC mimics its behaviour.

'Rather than triggering an alarm, you can keep going without derating performance too much,' adds De Filippi. 'You can implement advanced diagnostic strategies. Of course, you can also do this with standard electronics, but you are limited in how complex, fast and reactive your strategies can be. Performing those kinds of algorithms in real time, with no latency, we feel can make the difference.

'There are hundreds of thousands of different ways of making use of AI. The most common is when you have telemetry. You download data on the fly and run your strategy on a computer in the garage. In this case, we do it in the car.'

## Compact design

Size-wise, the VEC_480 matches the dimensions of its predecessor, the Marvel 480 VCU, despite now containing the onboard NPU. This means it is just over 20cm long and around 12cm wide. Marelli says it needed to modify the logic board to free up space to accommodate the NPU inside the box.

'Following the evolution of micro-controllers, you get micro-controllers with more peripherals integrated in the controller, more memory inside already, so you don't need external chips to add memory,' adds De Filippi. 'So, in a way, it comes easier now to get

Peugeot

**At 26 TOPS, Marelli Motorsport's new VEC is two and a half times more powerful than the company's current VCU, which is widely used in various motorsport disciplines, including endurance**

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**Marelli's Marvel SRG 480 VCU is currently used as a spec component in FIA Formula 2, and will be part of the new F3 car next year. The VEC is the same physical size, so could easily be integrated**

more calculation power and smaller dimensions. Instead of making the ECU a couple of centimetres smaller, we freed the space to add more functionality and make it more flexible and powerful.'

Aside from having to consider the physical integration of the NPU into the control unit, Marelli worked to enhance the VEC_480's thermal resistance. 'It's a matter of changing the layout inside the boards,' explains Compagni. 'This device has more than one board, so it's about how the thermal flows move inside. You support that with thermal conductors. We hope – because this is still under development – that the applications [teams] run on it will be able to self-throttle at the right level, in order to reduce heat and power consumption. I don't know what will happen if it's turned on 100 per cent of the time! As soon as we have a real application, we will be able to trim some of the details a bit better.'

## Upcoming rollout

Marelli is planning to launch the final spec of the VEC_480 soon, delivering the finished product to customers in Q2 or Q3 of 2025. This will be the first product released as part of a family that will accommodate different requirements. The designation '480' refers to the device having four connectors and eight cylinders. There will also be a VEC_340 with three connectors and four cylinders. The zero marks the product's revision number, leaving space for updated versions to come. Marelli is also planning to introduce an accident data recorder with an onboard NPU.

**'The platform will be fully open [so] our customers will be able to put their own neural networks inside, depending on the application'**

*Paolo Compagni, vice president of business development at Marelli Motorsport*

'We will have different sizes and versions, with or without ignition drivers,' explains De Filippi. 'The [launch version of the VEC_480] is for hybrid vehicles, where you can control both the thermal engine and the electric part with ignition / injection. For pure electric vehicles, we can get rid of the ignition / injection driver, making it smaller, but with the same calculation power. Or we can make it more extreme, if you want to add the unit to an existing electronic layout where you use it as an additional computer. If you add it on top of an existing electronics system, closing the loop can be a bit trickier in terms of latency, but it's possible.'

Marelli is not providing an AI framework for customers to install in the VEC_480. Instead, it expects them to bring their own software libraries. The unit is compatible with TensorFlow, Keras, PyTorch and ONNX.

'The platform will be fully open,' adds Compagni. 'It means our customers will be able to put their own neural networks inside, depending on the application. We decided not to provide anything because we are a component manufacturer, not a vehicle manufacturer. Of course, we can support, but the concept is to make this fully open to allow the most flexible and precise device that anyone can apply to their application or mission profile.'

With the launch of its VEC range, Marelli is aiming to push the boundaries of vehicle control unit development. In doing so, it is also contributing to the permeation of AI in motorsport, researching and developing solutions that are set to appear in the future.

'At the end, we built a tool that, hopefully, is ready for what's coming,' concludes De Filippi. 'In most top championships, teams are writing their own software and strategies, but this is the answer to what we felt was getting more important: the need to add flexibility to deal with AI embedded onboard in an easy way.'

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# Hand calculations

## A critical engineering skill that must be brought back to the forefront

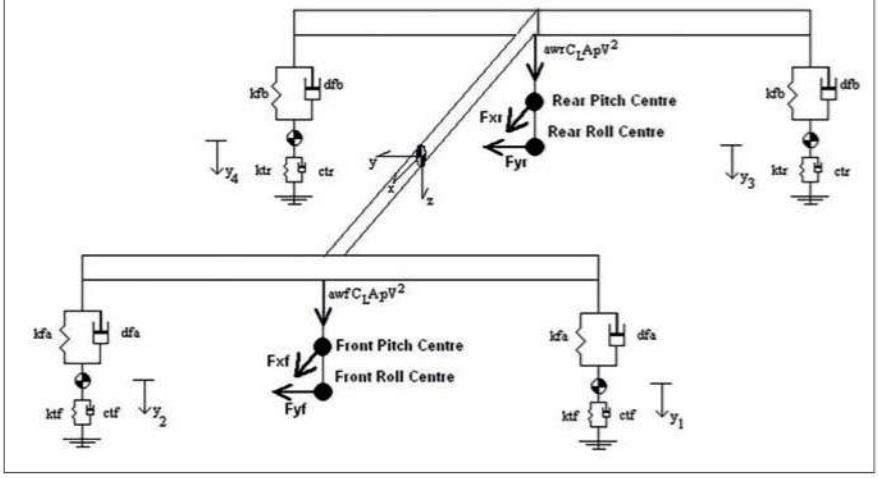
**By DANNY NOWLAN**

One of the signature features of all the articles I write for *Racecar Engineering* is my use of formulae and hand calculations to articulate an engineering point. This ability to mathematically explain what you are saying is a core engineering skill, the importance of which should never be underestimated. The reason I have written a number of articles on this topic over the years is because it is a skill I have noticed to be dangerously atrophying in the last two decades.

The ability to do hand calculations, calcs for short, is one of the definitive characteristics of being an engineer, and in this regard we are now at crisis point. On a micro level, I've been recruiting for interns again recently and am truly shocked by what I am finding. On a macro level, this lack of ability to do basic hand calcs is now making its presence well and truly felt.

If we wind the clocks back 45+ years, the SR-71 Blackbird was designed by 35 engineers working with slide rules and drawing boards. Prior to that, we were able to send people to the moon using computers less powerful than we all now carry around in our pockets. Fast forward the tape to today, and you only have to look at the delays and cost blow outs in projects such as the Airbus A380 and F-35 Lightning fighter jet to know something is seriously amiss.

**Fig 1: Beam pogo stick model of the racecar**




The reason we've arrived at this point can be traced directly to the overriding view that emerged in the mid-1990s – that computer-aided engineering (CAE) tools could completely replace traditional calculation techniques.

## Important lesson

On one level, that may well be correct, because you will never be able to hand calculate the downforce on a Formula 1 car, or resolve the stresses placed on a carbon fibre monocoque to within one per cent using pen and paper.

However, the important lesson lost along the way is that hand calculations allow engineers to quickly approximate the end result they expect to see. The loss of this core skill has put an ever-increasing reliance on CAE tools, to the point that we now have a generation of engineers without awareness of what the numbers are – or should be – and where they come from. This situation needs to change.

The good news is that it can be addressed easily, and I will illustrate via example in this article. You'll see for yourself what happens

**Fig 2: Ideal place to zero**

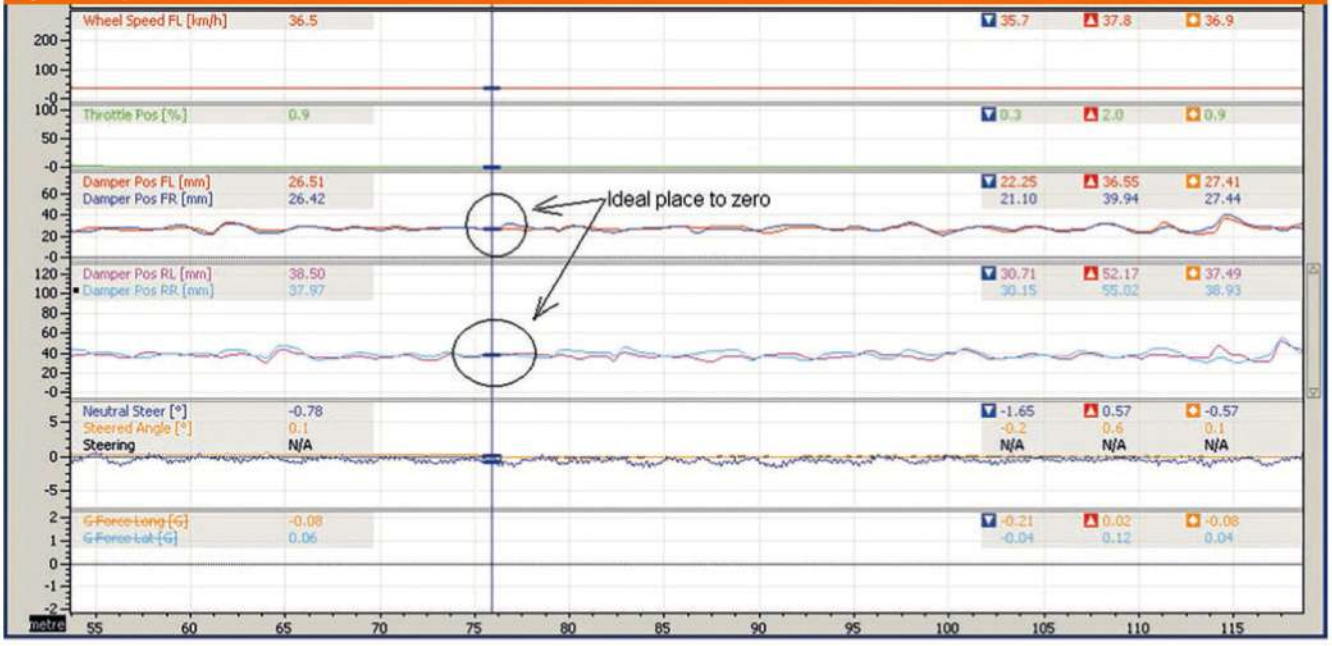
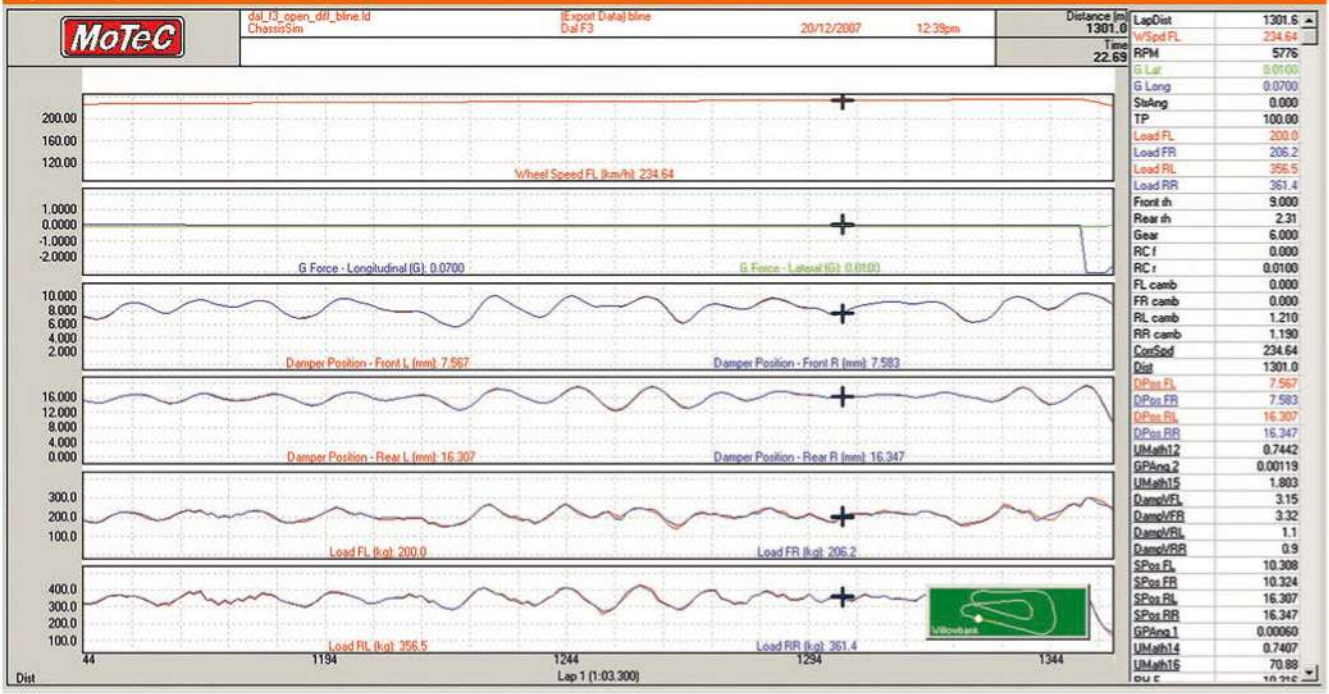


**Fig 3: Best point to take hand calculations for aero from**


MoTeC
Wheel Speed FL (km/h): 234.64
G Force - Longitudinal (G): 0.0700
Damper Position - Front L (mm): 7.567
Damper Position - Front R (mm): 7.583
Damper Position - Rear L (mm): 16.307
Damper Position - Rear R (mm): 16.347
Load FL (kg): 200.0
Load FR (kg): 206.2
Load RL (kg): 356.5
Load RR (kg): 361.4
Lap 1 (1:03.300)

when working from first principles, how applying some simple maths can give you a very close approximation of what to expect. More importantly, if you master this skill, it will give you a sixth sense of what to expect before you even do the hand calcs.

A case in point here is the legendary aeronautical engineer, Clarence 'Kelly' Johnson. Just by looking at an aerospace structure, he could tell what the pressure distribution would be on it to within a couple of tenths of a psi. An extraordinary skill.

## Calculating downforce

The first example I'll discuss is hand calculating downforce. I realise this is an example I repeat *ad nauseam*, but I am still astounded by the amount of motorsport engineers that can't do this. As usual, where it all comes from is the force balance of the beam pogo stick model of a racecar, as shown in **figure 1**.

**Table 1: Sample values for an aero hand calculation**

| Item | Quantity |
|---|---|
| Front motion ratio | 0.9 |
| Rear motion ratio | 0.8 |
| FL damper / FR damper | 10mm/10mm |
| RL damper / RR damper | 15mm/15mm |
| Front spring | 140.1N/mm (800lbf/in) |
| Rear spring | 140.1N/mm (800lbf/in) |
| Torque at rpm | 200Nm |
| Rolling tyre radius | 0.28m |
| $a_x$ | 0g |
| Vx | 220km/h |
| Gear ratio value | 3 |
| $m_t$ | 500kg |
| H | 0.3m |
| Wb | 2.6m |

**Master this skill [and] it will give you a sixth sense of what to expect before you even do the hand calcs**

If you have a racecar with downforce being applied to it, a free body diagram will readily reveal that the sum of the forces on the springs will equate to the downforce. For open wheelers, this doesn't take into account wheel lift. However, it is still sufficient to calculate pitch sensitivity and ground clearance. Look at it another way, when you start running $C_LA$ north of two, you ignore this information at your peril.

To kick this discussion off, we need to talk about zeroing conventions. The best procedure is to look at the data and zero the dampers on the ground, or apply an offset as they are coming out of the pits. A good procedure for doing this is illustrated in **figure 2**.

As can be seen from the data, the dampers are level, which will give us a very good measure of the zero condition.

The next step in the process is to identify where to perform the aero calculation. The best place to take the numbers for this is either the fastest point in the circuit or the longest straight. Whichever you choose, priority should always be the car going in a straight line with minimum lateral acceleration. The optimal point to take it from is shown in **figure 3**.

It is also wise to filter the data. I like to take a low pass frequency filter of, say, 1Hz. That said, I still like looking at the raw data because it gives me an idea of what the car is doing.

$$\begin{aligned} FtDownforce &= MR_f \cdot k_f \cdot (FL\_Damp + FR\_Damp) \\ &= 0.9*140.1*(10+10) \\ &= 2521.8N \\ RrDownforce &= MR_r \cdot k_r \cdot (RL\_Damp + RR\_Damp) \\ &= 0.8*140.1*(15+15) \\ &= 3362.4N \\ C_LA &= \frac{FtDownforce + RrDownforce}{0.5*1.225*(220/3.6)^2} \\ &= 2.57 \\ AeroBal &= 100 \cdot \left( \frac{FtDownforce + \frac{mt \cdot g \cdot a_x \cdot h}{wb}}{FtDownforce + RrDownforce} \right) \\ &= 100 \cdot \left( \frac{2521.8 + \frac{500 \cdot 9.8 \cdot 0 \cdot 0.3}{2.6}}{2521.8 + 3362.4} \right) \\ &= 42.9\% \\ C_DA &= \frac{gr*T/r_t - m_t \cdot g \cdot a_x}{0.5*1.225*(220/3.6)^2} \\ &= \frac{3*200/0.28 - 550 \cdot 9.8 \cdot 0}{0.5*1.225*(220/3.6)^2} \\ &= 0.937 \end{aligned} \quad (1)$$

Once these points have been established, you can start to calculate the downforce. The best way to illustrate this is by example, in this case an F3 car. The results are shown in **table 1**.

Here, all motion ratios are damper on wheel, and the gear ratio is engine / wheel velocity. For simplicity, I've omitted bump rubbers. Crunching the numbers, we see that shown by **equation 1** above.

This is no more complicated than high school level maths, yet it can tell you a great deal about what the racecar is doing.

The next example comes from one of the most extraordinary technical discussions I have witnessed over the last three years. Extraordinary for all the wrong reasons because not only did it illustrate a lack of ability to do hand calcs, but also a total lack of knowledge of engineering first principles. Regular readers will know instantly where I'm going next.

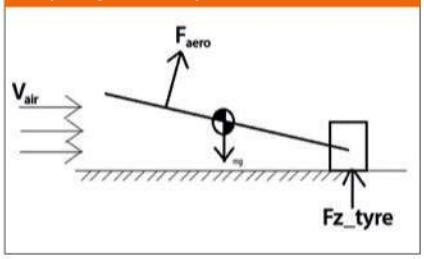
## Roll with it

The discussion was about aerodynamic-induced roll over of a racecar. This is a problem that plagues modern sports prototypes, but not so much the FSAE student cars the discussion was about. One could perhaps forgive one person becoming over excited and overlooking the obvious, but you should have seen the encouragement that followed to do detailed CFD studies of this scenario. I was so shocked that I forwarded it on to colleagues of mine who were aerodynamicists in various senior categories and they too were stunned by what they were reading.

To explain why this discussion was so off the mark, you only have to do some rough approximations of the mechanisms involved in an aerodynamic-induced roll over. The situation occurs when a car gets sideways at speed, its aerodynamic downforce reduces and it hits a bump, exposing the underbody to the open airflow, which causes it to cartwheel over.

Believe it or not, we can put some basic numbers to this to see whether we have a problem or not. The situation is summarised in the free body diagram shown in **figure 4**.

**Fig 4: Aerodynamic-induced roll over free body diagram analysis**




To keep this discussion simple, I'm going to assume the car has gone sideways, so isn't producing any downforce. As we can see, we have two major forces in play. The first is the lift produced by the underbody as a result of being exposed at an angle to the airflow. This will be applied at the quarter chord and is what is going to roll us over. The thing that is keeping us in check is the car's weight. What we need to do, then, is to take moments about the tyre still on the ground. If the aerodynamic moment exceeds the moment produced by the car's weight, it will flip over.

The trick is to come up with an approximation for the aero forces, and that's easier than you might think. Our goal here is not to try and predict the roll over moment, we just want to see whether we have a problem.

**The trick is to come up with an approximation for the aero forces… Our goal here is not to try and predict the roll over moment, we just want to see whether we have a problem**

To that end, we can look at some typical $C_L$ vs angle of attack plots of an aerofoil to obtain some ballpark figures. As rough as this may seem, in a roll over situation, this is pretty much what we are dealing with.

In terms of some rough $dC_L / da$ numbers ($a$ being in radians) $2\pi$ is an okay place to start from. Since this is a non-ideal aerofoil, let's approximate $dC_L / da$ at five. Let's then assume we've hit a bump, and the angle of attack is five degrees. Given a typical underbody area of a sportscar of, say, 10m$^2$, the aero forces we are going to generate will be given by **equation 2**.

$$F_{aero} = \left(\tfrac{1}{2}\right) \cdot \rho \cdot V^2 \cdot C_L \cdot A$$
$$= 0.5 \cdot 1.225 \cdot V^2 \cdot 5 \cdot \left(\frac{5\pi}{180}\right) \cdot 10$$
$$= 2.67 \cdot V^2 \quad (2)$$

Let's then assume car width is 2m and car weight is 1000kg. Taking moments about the tyre, we see that shown by **equation 3**.

$$M = F_{aero} \cdot \frac{3}{4} \cdot t - m \cdot g \cdot \frac{1}{2} \cdot t = t \cdot \left(F_{aero} \cdot \frac{3}{4} - m \cdot g \cdot \frac{1}{2}\right) \quad (3)$$

When we are going to have problems is when **equation 3** is equal to zero. Putting **equation 2** into **3** and solving for the zero condition, we see that shown by **equation 4**.

$$F_{aero} \cdot \frac{3}{4} = m \cdot g \cdot \frac{1}{2}$$
$$V^2 = \frac{2}{3} \cdot \frac{mg}{2.67}$$
$$V = \sqrt{\frac{2}{3} \cdot \frac{mg}{2.67}} \quad (4)$$
$$V = \sqrt{\frac{2}{3} \cdot \frac{1000 * 9.8}{2.67}}$$
$$V = 49.467 m/s = 180 km/h$$

What all this tells us is that for our example, we need to reach 180km/h before we are at risk of aero-induced roll over. In reality, it's a little bit more than that (usually about 220-240km/h in most circumstances), but this is good enough as a ballpark figure.

Now let's see how these numbers look with an FSAE car. Using the same aero figures as the sports prototype (which I have already demonstrated is giving the aero roll over scenario considerable benefit of the doubt) **table 2** shows the other relevant numbers for a typical FSAE car.

**Table 2: Sample values for an FSAE car**

| Parameter | Quantity |
|---|---|
| Total mass | 250kg |
| Width | 1.5m |
| Floor area | 2m$^2$ |

Reviewing **equation 2**, this time for the FSAE car, we have that shown by **equation 5**.

$$F_{aero} = \left(\tfrac{1}{2}\right) \cdot \rho \cdot V^2 \cdot C_L \cdot A \quad (5)$$
$$= 0.5 \cdot 1.225 \cdot V^2 \cdot 5 \cdot \left(\frac{5\pi}{180}\right) \cdot 2$$
$$= 0.534 \cdot V^2$$

Plugging this into our analysis for **equation 4**, we see that shown by **equation 6**.

$$V = \sqrt{\frac{2}{3} \cdot \frac{mg}{2.67}}$$
$$V = \sqrt{\frac{2}{3} \cdot \frac{250 * 9.8}{0.534}} \quad (6)$$
$$V = 55.3 m/s = 199 km/h$$

Doing the maths tells us that we can expect to see an aero roll over situation present itself for an FSAE car at approximately 200km/h. Given that FSAE cars are limited to approximately 110km/h, it would be physically impossible for this to happen.

I should also add that, in sideways view, an FSAE car has all the aerodynamic attributes of a brick so, if we really wanted to get aggressive with this analysis, the predicted roll over speed would go up quite significantly.

The point I'm making is that by using first principles, together with some high school maths, we've shown why the discussion I witnessed was not just pointless, but ridiculous. More so the fact that members of the discussion group were so willing to commit valuable time and resource to modelling the scenario.

## Try it yourself

As a footnote, I should mention that there *was* an FSAE roll over in 2014 with a winged car. This was brought to my attention in a lecture I gave, which caused me to look into it in more detail.

The situation occurred in an Autocross event, where cornering speeds are generally below 60km/h. So, what could be going on here? I could tell you the answer but, for any Formula Student / FSAE competitors reading this, I'm going to let you do the work. Suffice to say, peak lateral $g$ for an FSAE car lands at about two. Also, all of those big wings push the c of g height to 0.3m or so. So, with a mass of 280kg and a track of 1.2m, what is the dominant term? Is it mechanical or aero? Answers on a postcard please, showing the hand calcs of course.

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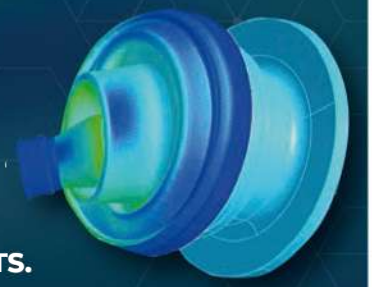

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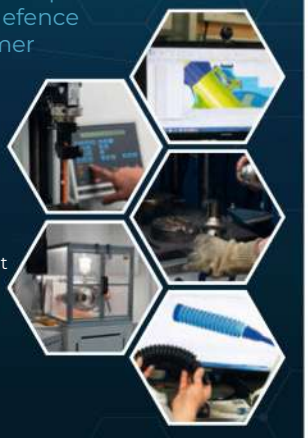

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**Fig 5: Pitch data not correlating**

## No correlation

Another excellent case study of how to use hand calcs is what happens when your simulated and actual data don't correlate. A couple of years ago, I had a touring car customer who couldn't get their front pitch data to correlate. The situation is illustrated in **figure 5**.

As always, actual data is coloured, simulated is black. As can clearly be seen, the correlation is very good, with the exception of braking. Rather than throwing your hands up in the air and saying simulation is a waste of money, take a moment to use some hand calculations to shine a light on what is going on.

The great thing about hand calcs is they provide a simple, but powerful way of isolating what the problem is. One of the variables that the ChassisSim software package returns is the applied longitudinal forces and pitch centres. This means you can sanity-check the numbers you are getting back from your simulation results. While I am unable to give you specifics on this particular example, let me walk you through how you would do it. **Table 3** gives some parameters for an equivalent touring car.

Using these pieces of information, we are in a position to hand calculate what the expected pitch should be. Crunching the numbers, we see that shown by **equation 7**.

$$LT_{SM} = \frac{F_{BF}\cdot(h - pc_f) + F_{BR}\cdot(h - pc_r)}{wb} \quad (7)$$
$$= \frac{9.8*1224.5\cdot(0.43 - 50e-3) + 9.8*885\cdot(0.44 - 180e-3)}{2.794}$$
$$= 2408N$$

Then, calculating what we should expect to see at the damper can be shown by **equation 8**.

$$\partial Damp\_ft = \frac{0.5*LT_{SM}}{k_f\cdot MR_f} \quad (8)$$
$$= \frac{0.5\cdot 2408}{122.6\cdot 0.63}$$
$$= 15.6mm$$

When this was calculated on the actual car, it was found that the simulated data was behaving as it should. That was an instant red flag that something was not right, and illustrates the power of using both CAE tools and hand calculations together.

## Jet wash

The ultimate power of hand calculation is they are engineering's very own bullshit detector. A perfect case in point here is the maximum claimed speed of the F-35 fighter jet. Air Force chiefs all over the western world, and the plane's manufacturer, Lockheed Martin, have claimed the F-35 can hit Mach 1.6 at altitudes greater than 30,000ft. But can it do that where it counts, in a straight line?

Let's use some hand calcs to find out. The first step is to solve for velocity vs time using the differential equation that describes aircraft straight and level performance, as shown in **equation 9**.

$$\frac{dV}{dt} = \frac{T - 0.5\cdot\rho\cdot V^2\cdot C_D A}{m_t} \quad (9)$$

**Where,**

| | | |
|---|---|---|
| $V$ | = | Aircraft velocity (m/s) |
| $t$ | = | time (s) |
| $P$ | = | Air density (kg/m3) |
| $C_D$ | = | Co-efficient of drag |
| $A$ | = | Aircraft wing area (m2) |
| $T$ | = | Engine thrust (N) |
| $m_t$ | = | Aircraft weight (kg) |

When you do a bit of manipulation, the identity you'll be solving is **equation 10**.

$$dt = \frac{m_t\cdot dV}{T - 0.5\cdot\rho\cdot V^2\cdot C_D A}$$
$$\int\frac{dV}{a^2 - V^2} = \frac{\tanh^{-1}\left(\frac{V}{a}\right)}{a} \quad (10)$$
$$a = \sqrt{\frac{T}{0.5\cdot\rho\cdot C_D A}}$$

The next bit of information we need is flight performance. In this instance, the data comes courtesy of the US Department of Defence. In 2011, the F-35's transonic acceleration from Mach 0.8 to Mach 1.2 was downgraded to 63s at 30,000ft International Standard Atmosphere conditions. So, all you need to do is curve fit the results from solving **equations 5** and **6** to this performance specification. You can then use this to solve for the CD and the maximum speed will pop out in the wash. I'll let you do the calcs and find the results for yourself.

In closing, being able to do hand calcs is a vital skill that all engineers *must* possess. It's not too late for the industry to recover; it's just a matter of re-learning the basics and being methodical and patient. The pay off, shown in the examples here, is invaluable insight that could save you a great deal of time, money and resource in not chasing ghosts down blind alleys. You've got to hand it to hand calcs.

**Table 3: Touring car parameters**

| Variable | Value |
|---|---|
| Front motion ratio (damper / wheel) | 0.63 |
| Front spring rate | 123N/mm |
| Front braking force | 1224.5kgf |
| Rear braking force | 885kgf |
| Front pitch centre | 50mm |
| Rear pitch centre | 180mm |
| C of g height | 0.43m |
| Wheelbase | 2.794m |

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# WRC drops hybrids for Rally1…

**The FIA World Rally Championship** will drop hybrid systems from its premier Rally1 class next year, having previously rowed back on that position earlier in 2024.

Approved at an electronic vote of the FIA World Motor Sport Council, Rally1 cars will become 80kg lighter without the electric motor and battery. The air restrictor diameter will be reduced from 36mm to 35mm in an effort to maintain the same power-to-weight ratio as this year.

A spec hybrid system from Compact Dynamics was introduced in 2022, giving the cars a 100kW (134bhp) boost. With the boost active, and combined with the 1.6-litre engine, cars produced a total output of more than 500bhp.

The FIA originally announced in February that hybrids would be scrapped in 2025. One of the cases that was made, and is now being made again, was that hybrids make it difficult for drivers of non-hybrid Rally2 cars to progress into the WRC's top tier. The governing body then made a u-turn in June, opting instead to keep hybrid-powered Rally1 unchanged until 2027, giving the manufacturers ample time before altering their cars. The FIA then reverted to its February position after further deliberation.

'Following extensive dialogue with key stakeholders, it became clear that continuing to use the plug-in hybrid units provided under the existing supplier agreement was no longer in the best interests of the FIA World Rally Championship,' says FIA chief technical and safety officer, Xavier Mestelan-Pinon. 'We can now move forward in full confidence that the WRC becomes even better and stronger, with developments that are in line with the working perspective for the 2027 technical regulations.

'Once again, we have highlighted the championship's ability to adapt without diluting the sporting spectacle, while at the same time responsibly embracing the challenges of our times. We are also pleased that the use of 100 per cent sustainable fuel remains a cornerstone of the championship's commitment to reducing its environmental impact.'

**This season has been a rollercoaster year for the WRC's technical regulations; hybrids are officially off the table (again). Using 100 per cent sustainable fuel remains a key ingredient of the series**

# …as BTCC treads a similar path

**The British Touring Car** Championship has also announced it will also drop hybrid systems from its cars next year after three seasons running the electric powertrain boost technology. In its place, the series will introduce a 100 per cent sustainable fuel from Haltermann Carless called Hiperflo ECO102 R100, replacing the 20 per cent sustainable solution currently used. The new product has been dyno tested by the various engine builders over the last few months.

The BTCC hybrid system, supplied by Cosworth, replaced success ballast as the series' method of pegging back successful drivers to promote dramatic racing. Those with better prior results were allowed fewer laps in which they could apply a 15-second boost from the hybrid system and turbocharger. After complaints that the racing became less exciting, the BTCC upped the turbo's contribution, doubling the amount of total boost to 60bhp. The electrical system was not uprated in this change due to limitations of having a 48V battery.

Removing the electric motor and battery is projected to save around 55kg in each car. A form of boost system will be retained as the turbo will take up 100 per cent of the task.

Despite its hybrid system being dropped, Cosworth will control the boost through its electronics suite.

**BTCC hybrid unit supplier, Cosworth, is set to remain involved in the series as its electronics and boost control partner**

'The hybrid era was a great one for the BTCC,' said series chief executive, Alan Gow. 'Six years ago, when we first announced hybrid, the technology was still in its infancy within motorsport. We've successfully completed that programme, and have no more to prove in that respect. As we've now ticked that box, we can move further forward with the introduction of fossil-free sustainable fuel whilst, very importantly, delivering the same performance parameters that made this year's BTCC such a memorable one.'

# Euro NASCAR adopts sequential gearbox

**The NASCAR Euro Series will adopt** a five-speed sequential gearbox in 2025, departing from its traditional H-pattern manual in a major change.

Announced at the Professional MotorSport World Expo in Cologne, the championship has struck an agreement with Lithuania-based Samsonas, which will provide its RS90 transmission to all cars next year. The new gearbox is a versatile unit that can be adapted to any rear-wheel-drive racecar, and has been used extensively in drifting.

Samsonas fitted an adapter plate to accommodate the Euro Series car's bellhousing and added a specialist clutch shaft. The package was trialled in race conditions at this year's season finale and will be fitted to more cars in a driver recruitment test at Oschersleben this month.

NASCAR Euro Series sporting and technical director, Joe Balash, said the change was made for multiple reasons, including aligning with NASCAR's direction in North America, reducing the likelihood of expensive missed shifts and increasing options for drivers racing through corners. He added that competitors had been asking for a sequential 'for years'.

NASCAR Euro Series

**Samsonas' supply of a spec NASCAR Euro Series gearbox was announced at the PMW Expo in Cologne**

The move to sequential shifting is part of a steady technical overhaul of the NASCAR Euro Series vehicle. The so-called Gen 3 package will include several new features that will be rolled out gradually to soften the cost burden for teams. It is understood that a switch from carburettors to fuel injection is being considered, ahead of a planned move to renewable fuels in the future. Series organiser and chassis builder, Team FJ, is set to continue using the original steel tube frame design that has been active since the first season in 2009.

It remains to be seen how lap times will be affected by the move to sequential shifting. The test car at the Zolder season finale qualified 16th, although its purpose was to validate the systems, rather than demonstrate outright performance.

# Mercedes F1 power units for Alpine

**Alpine will use Mercedes power** units and gearboxes for its Formula 1 cars when the new regulations come into force in 2026.

The multi-year agreement sees Alpine transition from being a factory team to a powertrain customer, following the announcement in September that its Viry-Châtillon plant in Paris will cease producing F1 engines after next year. Mercedes' deal to supply Alpine with its Brixworth-built power units will be valid until 2030 at least.

Alpine, which is based between Viry in France and Enstone in the United Kingdom, will effectively replace Aston Martin in Mercedes' customer line up as Aston is moving to Honda power units from 2026, when the championship adopts 100 per cent sustainable fuel. McLaren and Williams also currently use Mercedes power and are set to continue with their agreements into the next rules cycle.

An Alpine statement read: 'The team remains focused on performing in the strongest way possible in the 2024 and 2025 seasons.'

**Alpine's status as a works team will end in 2026 when it becomes a Mercedes power unit customer**

## IN BRIEF

**Formula 1** and **General Motors** have agreed in principle for Cadillac to enter the series as an 11th team in 2026. It comes 10 months after F1 rejected Andretti Global's proposed entry with GM support. Mario Andretti, who was a key player in that unsuccessful bid, has been named as a director on the Cadillac team's board.

Sportscar and IndyCar designer, **Bob Riley**, passed away in October at the age of 93. Riley worked on Ford's sportscar endeavours, including the 24 Hours of Le Mans-winning GT40 Mk IV, before establishing himself as a constructor that achieved success in the prototype and GT ranks.

Chinese electronics company, **Xiaomi**, has broken the four-door car lap record at the Nürburgring Nordschleife with its electric SU7 Ultra Prototype. The vehicle, sporting a tri-motor, all-wheel-drive system, clocked a 6m46.874s lap with last year's Nürburgring 24 Hours winner, **David Pittard**, at the wheel. Xiaomi plans to go for the EV production car record next year.

**Sauber** has created a new F1 head of race engineering role and appointed Italian engineer, **Giampaolo Dall'Ara**, to the post. Dall'Ara previously worked as the F1 team's head of track engineering and has run a consultancy firm since 2016. Sauber stated his appointment will 'optimise alignment on all car performance-related topics.'

**Marelli** has become a technical partner of **Nissan Formula E Team** in a two-year deal. In a statement, Nissan said the Italian engineering company will be able to 'develop and showcase its technical expertise' in electric racing.

**Cosworth** has widened its Antares ECU range with two new models. The Antares 4 and 6 offer high-rate synchronised data logging at lower cost than the 8, which is used in the BTCC, Super Formula Lights and the Aston Martin LMH car. The new units promise multi-pulse and stratified GDI control, active torque management and real-time PPU and BOP control.

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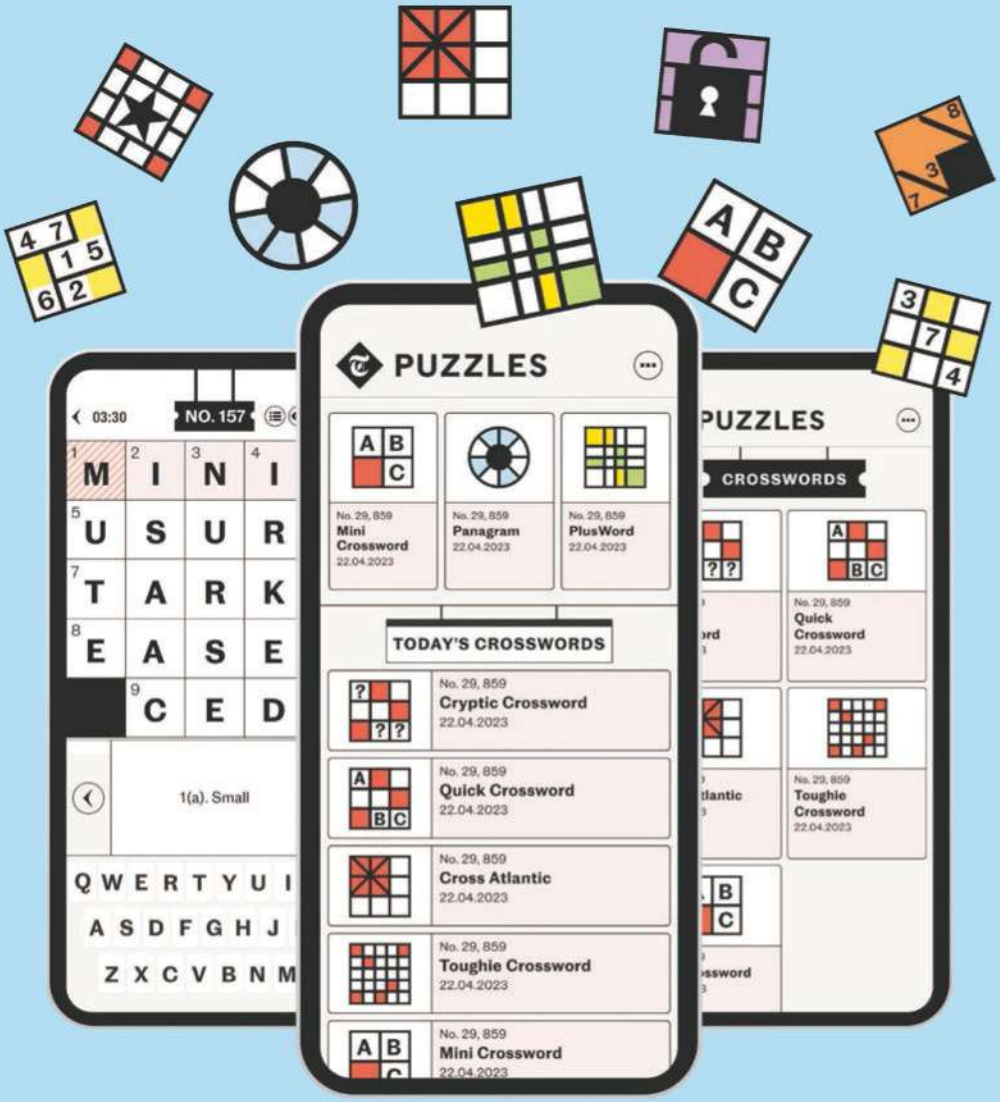


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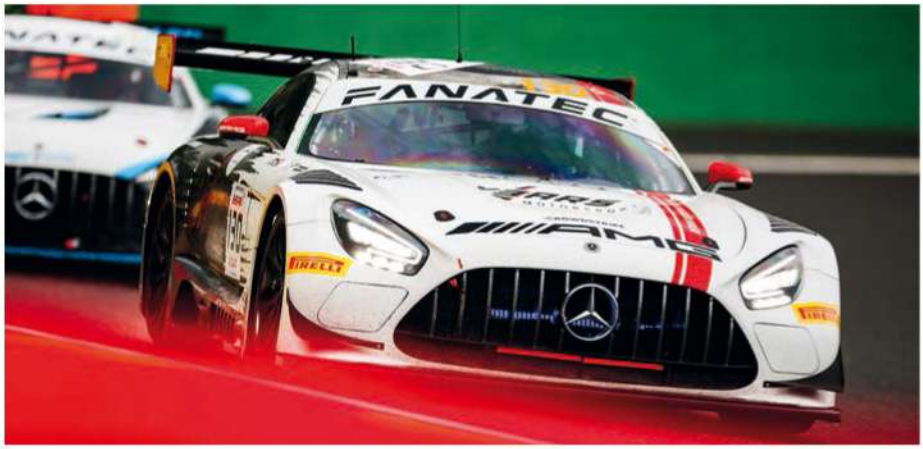
# Mercedes to Le Mans as Lamborghini leaves WEC




Mercedes-AMG

The winner of several major 24-hour GT3 races already, Mercedes-AMG now has a chance to compete for class honours at Le Mans

**Mercedes will return to the 24** Hours of Le Mans for the first time since 1999 next year with an LMGT3 programme run by the Iron Lynx team, which has switched from Lamborghini.

The German auto maker last contested the French endurance race 26 years ago as a factory squad. In recent years, it has been highly active in GT3 customer racing with its AMG high-performance division, but such cars were not allowed at Le Mans until this year. Mercedes-AMG wanted to join the party, and a guaranteed way to do so was to have a full-season FIA World Endurance Championship entry. However, it was denied a place on an over-subscribed WEC grid due to the organisers prioritising GT3 manufacturers that also had a Hypercar programme.

However, the departure of Lamborghini from both Hypercar and LMGT3 has helped to ensure there is space for two Mercedes-AMG GT3 Evos on the 36-car entry list.

Lamborghini struggled on its Hypercar debut this year with a single SC63, run and part-financed by Iron Lynx. It is now choosing to only run the car in the IMSA SportsCar Championship. This decision is linked to the WEC's new rule that each Hypercar brand must be represented by at least two cars.

Lamborghini will also be absent from LMGT3 after Iron Lynx's switch. The Italian marque described its WEC departure as a 'pause' for now.

Despite being new to the WEC, Mercedes-AMG is already a successful GT3 marque, having won major races such as the 24 Hours of Spa, Nürburgring 24 Hours and FIA GT World Cup in the last decade.

There will be 18 Hypercars on next year's grid, one fewer than 2024. This is because Isotta Fraschini has also left, while Jota has swapped its two-car Porsche customer effort for a two-car Cadillac factory stable, replacing Chip Ganassi Racing's sole Cadillac for a one car net loss. Two of the departed entries have been offset by the addition of two Aston Martin Valkyrie AMR-LMHs.

# Infrastructure injection for Bell and OMP

**Motorsport safety equipment** company, Racing Force Group, is updating its infrastructure at Bahrain International Circuit for two of its brands, Bell Racing Helmets and OMP.

The first strand is the expansion of the Bell headquarters to 12,000m$^2$. Bell provides helmets to 70 per cent of drivers on the Formula 1 grid and also runs a miniature collectable helmet business.

Construction has also started on a new factory for OMP, which supplies racewear, car parts and accessories. This will be a 15,000m$^2$ building located adjacent to the current one.

The developments have been spurred by a capital increase from Bahrain Mumtalakat Holding Company.

Bahrain has been a regional home to Racing Force and its brands since 2015. Other hubs are situated in Mooresville, United States and Ronco Scrivia, Italy.

'The completion of the Sakhir factory extension is another key step in this highly successful alliance,' says Stephane Cohen, co-CEO of Racing Force Group and Racing Force Bahrain.

'The link with the Bahrain International Circuit now includes the entire Racing Force Group and, following Mumtalakat's investment, we can announce the beginning of construction of a second building in Sakhir. The facility will be a strategic asset for increasing production of items in the OMP range, another benchmark brand in motor racing.'

Expansion of the Bell Racing Helmets facility in Bahrain is due to fresh investment into Racing Force Group

## IN BRIEF

**Dan Fallows** has been relieved of his position as technical director of the Aston Martin F1 team, but will remain part of the group.

**Peter Wright**, technical consultant on *Racecar Engineering*, has self-published a book entitled *How Did I Get Here?* It charts the first 78 years of Peter's life, from childhood through his years spent at Lotus and his work on safety with the FIA. He then goes on to ponder the future of the planet and electric racing. Available from www.howdidigethere.co.uk for £30

**EEC Performance Systems** has launched the E-POD WEC flowmeter display for sportscars. It can be used as a standalone module or as part of the E-POD wireless fuel stop system. Connecting to Sentronics' pit tank flow meter, it reads and records fuel flow rate, flow time, volume and deadman's position. Fuelling records can be viewed on display or transmitted wirelessly to the team's garage.

**BrightLoop** has been selected to supply a high-to-low voltage DC-DC inverter to the ACO's in-development H24EVO hydrogen prototype demonstrator car. The company has also worked in Formula E, Extreme E, LMDh and IndyCar.

**Ricardo** has launched a transmission range called Element. It is designed to reduce the time and cost of product development for customers in motorsport and high-performance automotive. The first Element product, a family of epicyclic reduction drives, was unveiled at the PMW Expo.

McLaren Formula E team principal, Ian James, is the new director of motorsport at **McLaren Automotive**. Rob Bell has become sporting director.

**Motorsport UK's** consultation on the use of sustainable fuels in British racing concludes in December. The body is proposing that all racing fuels contain at least 50 per cent sustainable content from 2026, as part of a roadmap to becoming 100 per cent fossil-free by 2030.

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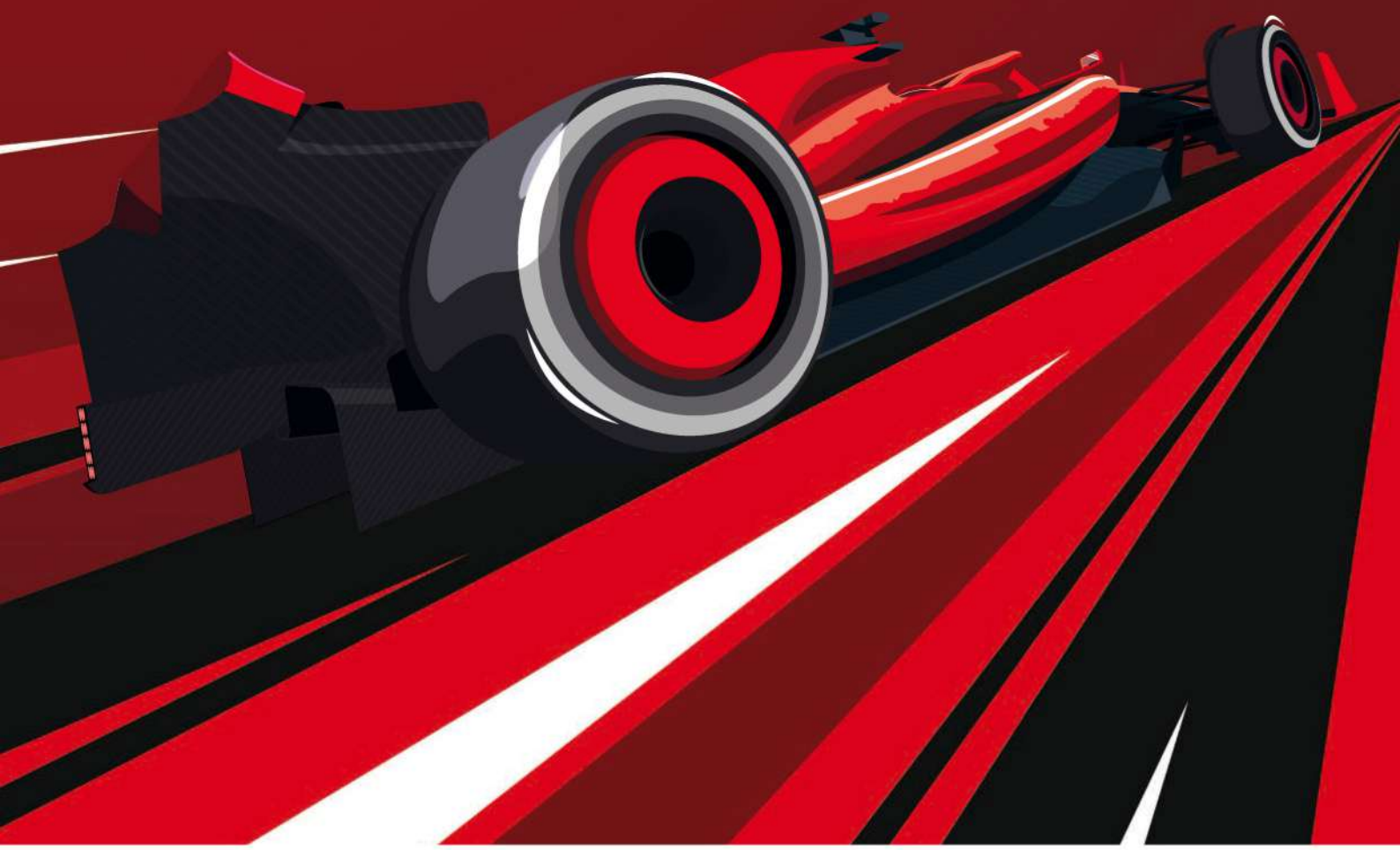

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# A time of change

## Next year looks to be a positive, but also unusually challenging

What a year 2024 was for the business of motorsport. So much change and so many diversions. As always, the resourcefulness and determination of our business leaders saw us through, but now 2025 looks even more challenging.

A dark cloud is gathering that could affect the vital bond between our sport and the automotive industry. This special relationship ebbs and flows over the years, brand by brand, series by series, but critical threats, involving governments and global trade, could change things.

The MIA's CTS24 motorsport technology trade show at the Silverstone Wing in October was an outstanding success. It brought together top-quality leaders and companies with eager collaborators and potential partners. From the many comments, it was the quality of the audience that was outstanding, alongside exceptional exhibits from a wide range of technologies affecting the future of motorsport.

Throughout the show, Speakers Corners were standing room only, and already over 35 per cent of stands have been sold for CTS25 - a positive sign to all.

## Leaders of change

This was a complex year for business around the world. Elections in Europe, the United States and the United Kingdom have left us with new political leaders who will affect our business realm. Many plan substantial changes; only time will tell whether they benefit motorsport or not. Sadly, armed conflicts continue to affect the wider world, which we all hope will be resolved speedily.

In the UK, the new government's economic changes certainly affect Motorsport Valley businesses, and not necessarily in a positive way. It is too early to identify any benefits, but costs will undoubtedly rise and employment will be negatively impacted in various ways.

Most motorsport series throughout 2024 attracted good audiences, and entries, with few exceptions. The governance of some faced difficulties, but most were resolved. Formula 1 has seen McLaren and Ferrari rising to the challenge and giving Red Bull a hard time.

Further down the F1 grid we witnessed exciting battles and talented new drivers, all keeping growing audiences entertained.

The 2025 season will see many series, including the FIA WRC and Formula E, launch plans to improve the competition and attract bigger audiences. This has a positive effect on sponsorship, the vital lifeline for our industry, and the supply chain.

It seems 2025 will be a good year for business generally, while we prepare for the substantial rule changes coming to many series in 2026. However, there is the matter of that black cloud I mentioned earlier. Cars have become a significant, and highly publicised, target by governments and society for action to reduce carbon emissions. Collectively, other transport sectors do more environmental damage, but cars are an easy target for politicians to demonstrate 'green' credentials.

**Motorsport has an important role to play in working with political and automotive leaders to find a range of solutions in the pursuit of net zero**

Motorsport embraced these challenges, launching Formula E many years ago, for example. It also declared determination and plans for various changes on its own journey to net zero, which is having an increasingly beneficial effect.

However, it appears politicians, and the wider automotive industry, misread or misunderstood a critical issue. In their urgency to be seen to make a difference, they undervalued the vital importance of market demand, and the need to take consumers along with their journey.

The dearth of charging points, chaotic prices of electric cars, perceived danger of fire, range anxiety, lack of parking spaces – the list goes on – has deterred buyers from investing in change.

Progress toward net zero *will* be made over time, but now the automotive industry is caught in a vicious circle. They have taken action to reduce, or even close, ICE manufacturing and product lines to focus on producing EVs to meet governmental legislation and guidance. They now face fines for selling ICE cars, yet demand for BEVs is far below expectations.

Somehow, both government and industry must find a solution. Financial damage to the industry and its supply chain is already substantial and thousands of jobs have been lost, with more sure to follow.

## Black cloud

The black cloud is that funding from OEMs, and their primary suppliers, will be under extreme pressure and, as a result, their vital investment in motorsport – in branding, technology or manufacturing – could be reduced. In the meantime, motorsport will continue to develop, compete and demonstrate to the public, solutions using ICE with sustainable fuels, as well as hydrogen *and* electric.

This issue is with us now, and will be discussed in detail with our audience at our popular MIA EEMS25 annual conference on 25 March at the British Motor Museum, Gaydon. This drastic change affecting the automotive industry, and the need for solutions, will make for a valuable and fascinating discussion.

I believe this role for motorsport, and Motorsport Valley businesses, will be welcomed by leaders in automotive and government. Showing that motorsport, a big part of the UK's automotive world, is actively pursuing a variety of solutions on its journey to net zero, with the aim of benefitting society as a whole. We must work hard to help our friends in the automotive industry overcome their difficulties however we can.

I end by wishing you every success in 2025, and even more in 2026. I hope we meet an MIA event in the near future. Please check these out at www.the-mia.com, or email me at info@the-mia.com

*Chris Aylett is CEO of the MIA (Motorsport Industry Association)* www.the-mia.com

**In their urgency to be seen to make a difference, [politicians, and the wider automotive industry] undervalued the vital importance of market demand**

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# Tough call

## GT3 teams in the WEC are facing a challenge to hit their budgets

The curtain came down on the 2024 FIA World Endurance Championship season with an eight-hour race in Bahrain. Toyota won the Hypercar manufacturers' title, despite one of its two cars having a fuel pump failure. Porsche won the drivers' title, even though its champions had their worst race of the year.

In the first of the LMGT3 seasons, Porsche's Manthey team sealed both the manufacturers' and teams' titles, but there are clouds on the horizon. One is that Lamborghini will not compete in the series next year, the other is that LM GT3 teams are struggling to hit their budgets, and season two could be even more challenging.

Estimates to run a GT3 car in the WEC range from four to more than five million dollars per car, per season. This mind-boggling figure is around double what it costs to compete in an international race series of similar length so, in Bahrain, I asked teams where the money was going. It seems travel budgets and entry fees soak up almost half, while expensive fuel and the introduction of torque sensors hasn't helped. Engineers are now needed to monitor and develop the sensors to make them work, but they are not the bulk of the budget.

**There isn't a GT3 car on the grid that is financed solely by the manufacturer**

## Financial enquiry

I then started to ask how the teams in the WEC's second-tier category are financed. Each LM GT3 manufacturer is represented by two cars, run by private teams, although the teams aren't fully paid to race like in a factory Hypercar setting. They do get some manufacturer help, but lots of manufacturers are hurting through production car sales at the moment and, if they were to support their WEC GT3 programmes fully, you could follow a logical trend to the class being in trouble.

By regulation, each LM GT3 car must have a bronze-rated driver. Such drivers pay to race, giving the teams a source of income. That's great for those at the front of the grid but, for those with an uncompetitive car, selling drives to offset the budget is a tough ask. Especially if drivers can compete in Europe or North America for less.

Interestingly, one change to the regulations for next year is that it will no longer be necessary for the bronze driver to qualify the car. Pity, as that's the amateur's one chance of the weekend to shine brightly with new tyres on.

It also appears manufacturers are not offering teams the level of support that might be expected in WEC. Some give vouchers to help with spare parts; others leave their customer teams to figure everything out for themselves.

Either way, there isn't a GT3 car on the grid that is financed solely by the manufacturer. Each of the cars is reliant on private money, and rich folk have options.

Bear in mind, this year's budget might not be entirely fair, as the cars had to be air freighted back from the season-opener in Qatar due to the Red Sea crisis. The WEC stepped up to help meet some of the extra cost, but not all of it.

## Cost reduction

It's clear the FIA is looking at how it can reduce costs and support the LM GT3 teams. One suggestion is to ensure the calendar avoids the need for air freight. Another is to increase the return on investment. There are a few ways this could be done. Coverage is currently held behind a pay wall online, but manufacturers have been campaigning to make it free to air, where possible, around the world. The only race that could, or should, be charged would be Le Mans. That would make it easier for teams to attract sponsorship.

The first year of LM GT3 was successful in that nine manufacturers competed to the end. More are looking to join, but costs must be brought under control if the customer teams are to survive another season.

Many manufacturers in Europe have issued profit warnings in the last few months, and there's no doubt there are question marks over the continuation of some sportscar programmes in general. Yet, depending on who you speak to, there are three or four further manufacturers rumoured to be interested in joining.

Mercedes has apparently completed a feasibility study of an LMDh prototype with a chassis constructor. That is not likely to arrive any time soon, but it no doubt helped to guarantee Mercedes a spot on the LM GT3 grid. Ford's name is also in the ring, though paddock rumours range from it has made a decision already to it's nowhere near ready. Right now, McLaren is considered the most likely candidate, but then we've been saying that for years.

It is interesting to chase these stories. At least people are talking about new manufacturers being interested, and can see a logical reason for them to join. This is a far cry from where endurance racing has been in the past. Clearly the cost of prototype competition is palatable, the organisation just needs to make the same true of GT3. In Bahrain, the FIA and ACO started that process and it will be interesting to see where they end up and how quickly they can get there.

**ANDREW COTTON** Editor

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